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SUMMARY AND INTERPRETATION OF SOME DANISH CLIMATE STATISTICS

S.E. Larsen and N.O. Jensen

Abstract. A summary of available Danish climate statistics is presented. The main physical processes of relevance are described along with a graphical presentation of the various climate parameters. The report further contains an appendix where the complete set of data used are tabulated.

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CONTENT

PREFACE

Numerous publications are available on aspects of the Danish climate. However, most of these are in Danish and therefore of little use to foreigners who do not read this language. For this reason we compiled the present summary of climate statistics in English, and it is our hope that it will be of some interest to English-speaking visitors to Denmark.

A large problem associated with presentation of climatic data is the diversity of the material. The main text of this report contains only short sections on each of the key parameters with a few illustrations, while we have collected the main tabulated data material in Appendix B. As a consequence of the substantial number of sources for this material the tables in Appendix B will be found to be both partly redundant and somewhat uneven either in the degree of details included or in the form in which the information is presented or the years used. However, we have found it valuable to have all the material collected at one place.

In the main text we have tried to keep an even level of complexity in the presentation. In spite of this the reader will find that some parametres have been discussed more thoroughly than others. This reflects partly differences in the amount of information, wich have been available to us on the different parametres. Partly it reflects differences in how much we have felt it necessary to include a description of the relevant physical process to facilate the understanding of the statistics of a given climate parameter.

We regret that it has not been possible to avoid completely the specialized words and concepts used in meteorology. They are defined when used and, in addition, further a list of definitions is collected in Appendix A.

The maps used in the report to depict geographical variations of the various climatic parametres show no names of locations. To help the reader to orient himself on these maps we have in Appendix C enclosed a conventional map of Denmark.

1. INTRODUCTION

From a climatological point of view Denmark, apart from Greenland and the Faroe Islands, can largely be considered as a single unit. Its climatology is determined by its geographical position: approximately in the middle of the north temperate climate zone, on the west side of the European land mass, and bordering on the North Sea, the temperature of which is determined by a warm ocean current, the Gulf Stream.

Therefore, the country has a maritime temperate climate, dominated by westerly winds and by frequent passings of low pressure and high pressure systems. As a result, the "usual" Danish weather is characterized by cool and unsteady summers and warm and changeable winters. However, it does happen occasionally that easterly winds dominate, carrying to the country the severe winters and hot summers of the continent.

To a large extent the description of the climate is expressed in terms of 30-year averages of the parameters considered. The generally accepted main 30-year periods are 1871-1900, 1901-30, and 1931-60; these are called normal periods. In this report we shall primarily use data from the period 1931-60. However, we shall take data from other periods as well, shorter where averages for a full 30-year period are not available, and longer where this is is possible and illustrative.

Corresponding to the 30-year time averages, parametres are often averaged over all measuring stations within the country to obtain one characteristic value called the national average. The national average of the normal value of any parameter will be given whenever possible, as it is the parameter value which can be considered most characteristic for the Danish climate.

However, it should be pointed out that a description of the climate for an area like Denmark necessarily must be somewhat fuzzy.

This fussiness comes from that the complex and time varying patterns of climate parametres are sampled by a relatively limited number of stations with varying efficiency and data quality.

Interpretation of the resulting data is a slow, difficult and often thankless task, as it is to build up a network of measuring stations which despite all problems offer some representativeness. Here we mostly shall neglect these problems, in that we present the data statistics as they are found. This is why the report title refers to "climate statistics" rather than just climate. On the other hand we do believe of course, that the statistics shown is representative for the climate of Denmark today, but in the text we have raised the problem of representativeness whenever relevant.

Based on the 1931-60 period we shall finish the introduction by a summary of monthly averages of important climatic parameters, their seasonal variation, and their typical variation across the country.

2. SUNSHINE, CLOUD COVER, AND RADIATION BALANCE

Due to its geographical position Denmark has the possibility of having between 17 hours of sunshine per day at midsummer and 7 hours at midwinter (see Table B1). However, due to cloud cover the country realizes only 9 hours in summer and 1 at winter, as daily averages.

The yearly variation of cloud cover and average number of sunshine hours per day is shown in Fig. 2.1. Here the recorded number of sunshine hours per day reflects both the astronomical variation of the length of the daylight period and the average variation of the cloud cover. It should be mentioned, however, that the sensitivity of the instrument used to record sunshine hours is limited. Thus the measured number of sunshine hours,

Table 1. Short summary of the Danish climate. The table displays yearly average, seasonal variation, and typical variation across the country for monthly averages of key climatic parametres.

Parameter	Monthly averages				Units
	Yearly average	Yearly variation Min.	Max.	Geographical Variation	
Temperature	8	-0.5	16.6	1	°C
Hours with sunshine	144	30	290	10% of value	hr/month
Relative humidity	82	72	91	10	
Cloud cover	64	53	78	20	% of sky
Precipitation	55	34	81	20	mm/month
Wind speed 10 m above terrain	5	4	6.5	2	m/s

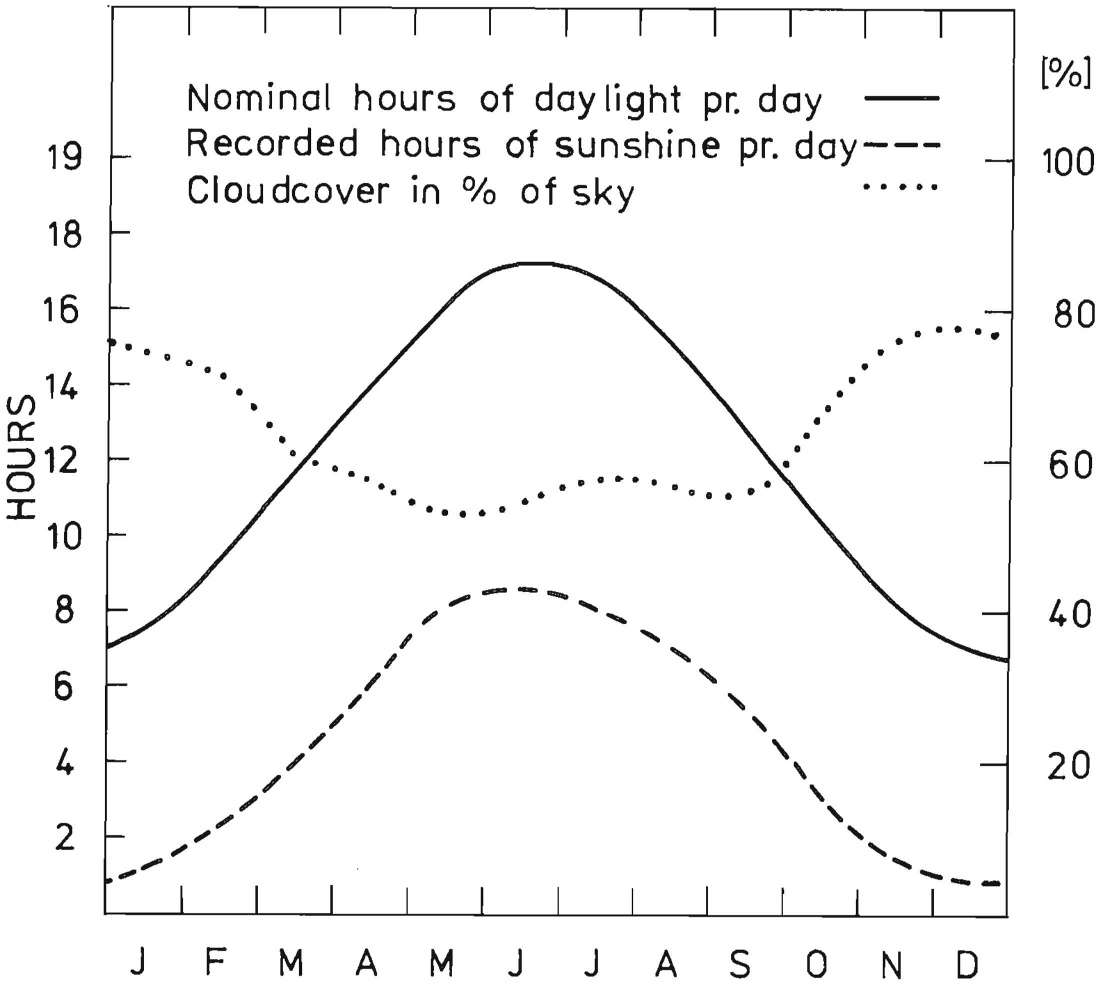

Fig. 2.1. Yearly variation of the length of the daylight period, shown together with the daily average of recorded hours with sunshine for Jutland and the Isles. Also shown is the yearly variation of the average cloud cover. The two latter curves are based on Table B2 rows 14 and 23. Note how the relatively constant cloud cover (albeit smallest in summertime) subtracts an almost fixed amount of sunshine hours from the theoretical value throughout the year.

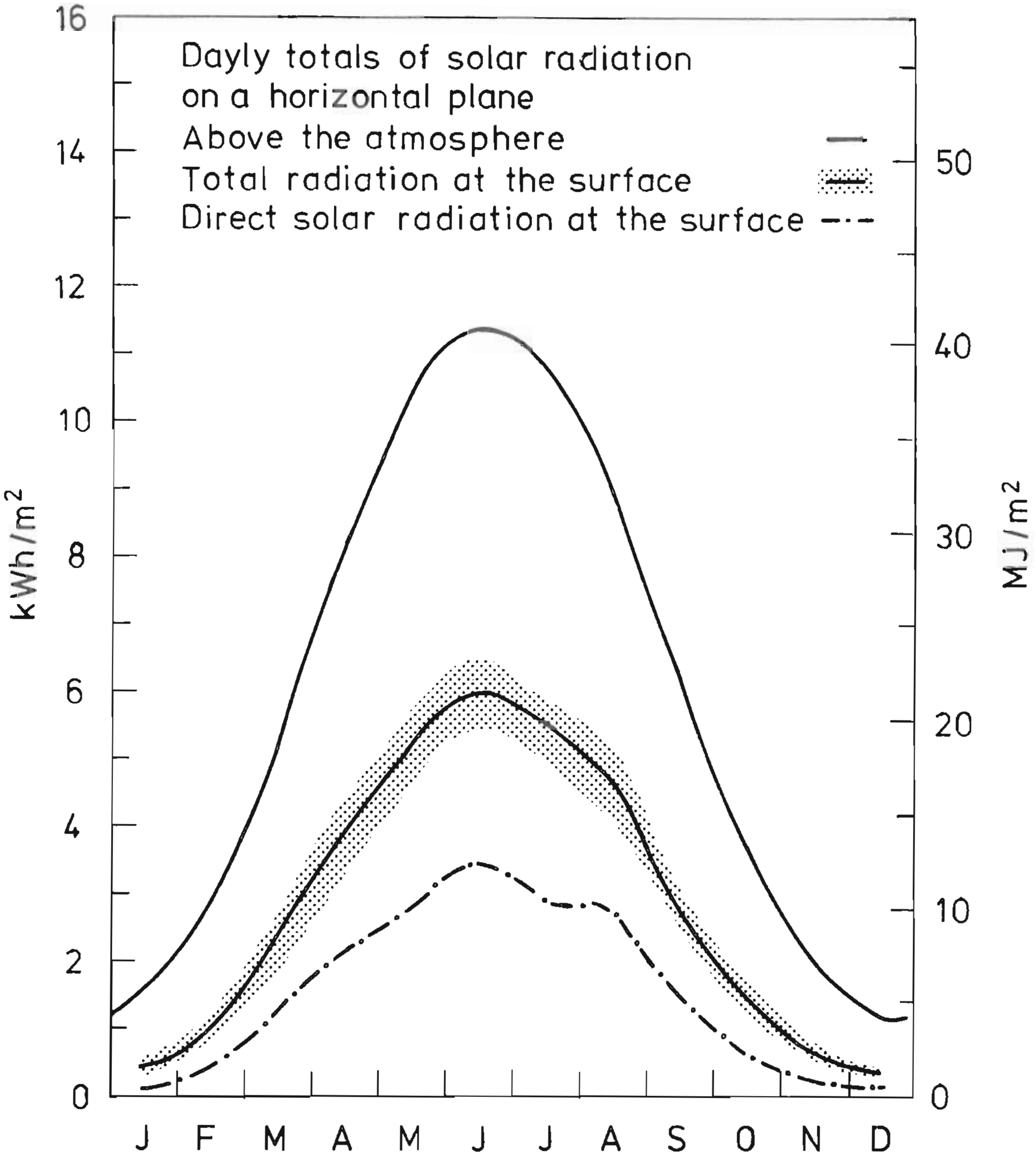

Fig. 2.2. Seasonal variation of the daily totals of incoming solar radiation on a horizontal plane. The upper curve shows the energy before the radiation passes through the atmosphere. The middle curve shows the total energy received at the surface. It is based on measurements in 1966-76 in Tåstrup (Højbakkegaard, 1966-1967, ---, 1977; and Teknologisk Institute, 1978). The boundaries of the hatched areas are the maximum and minimum values in the period considered The lower curve is the direct solar radiation for the same period. The numbers are found in Table B2. The latter curve especially shows the influence of the cloud cover, (see figure 2.1).

even with complete atmospheric transparency, would be about 1 hour less than the total daylight hours.

Corresponding to Fig. 2.1, the yearly variation of the incoming solar radiation is shown in Fig. 2.2. Throughout the year it is seen that roughly 50% of the radiation that reaches the top of the atmosphere during the daylight period penetrates to the earth's surface. The radiation received at the surface comes partly from the solar disk as direct solar radiation and partly from all directions as diffuse solar radiation. The partition between the two components is seen to occur at about 50% on an annual average. Naturally individual deviations take place in that the influence of the cloud cover is more pronounced for the direct than for the diffuse radiation, (compare Fig. 2.1).

As the earth's surface receives radiation from the sky and at daytime mainly from the sun, so of course does the surface radiate back to the sky. The incoming minus the outgoing radiation is called the net radiation.

From a meteorological point of view the net radiation is important because it is one of the main sources of surface heating (if positive) or cooling (if negative). This heating and cooling is in turn transmitted to the air above, and thereby the diurnal variation of the net radiation becomes the driving force for the diurnal variation of the flow field in the lowest kilometers of the atmosphere, called the planetary boundary layer. (See the discussion in Section 4 on the behaviour of the temperature).

Figure 2.3 shows the yearly variation of the total daily net radiation. A comparison with Figure 2.2 shows that in summer the daily total of net radiation is about 50% of the total incoming radiation. During winter, Denmark actually loses heat through radiation, but the figure also illustrates that over the year on the average Denmark has a positive net radiation. The surplus of heat is transported polewards by the atmospheric processes.

Figure 2.4 shows the diurnal variation of the net radiation for four characteristic month: the months of equinox, March and

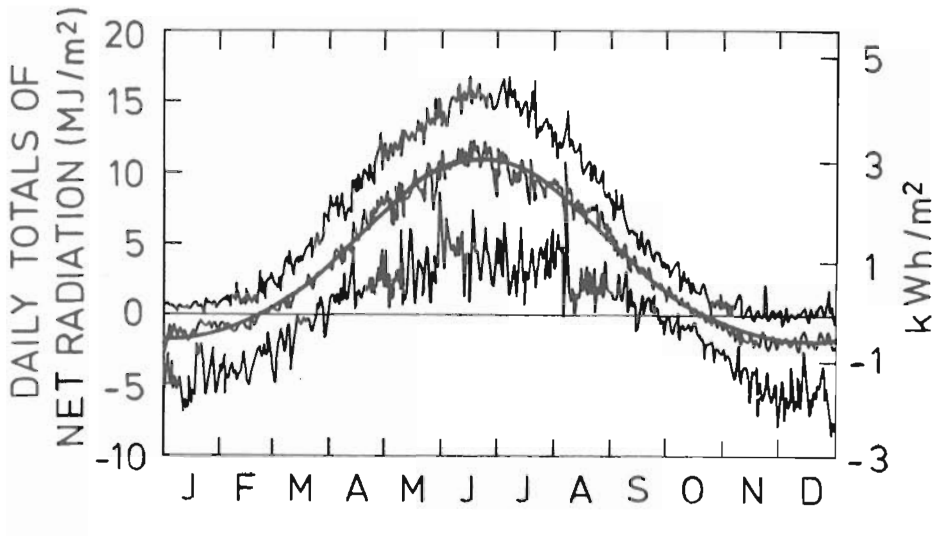

Fig. 2.3. The figure shows the seasonal variation of the total daily net radiation (i.e. integrated over the daily cycle) from the period 1966-1979. (Hansen et al., 1981). The curves depict the mean total daily net radiation as well as the extreme values for the period. The smoothed curve is a fit to the average data.

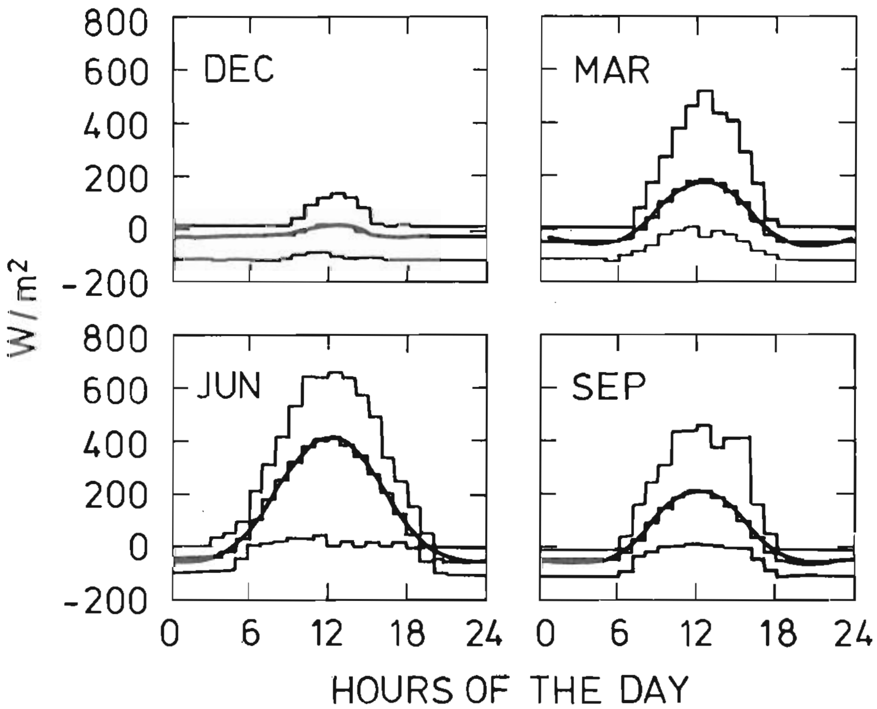

Fig. 2.4. Daily variation of the net radiation during the equinoctial months, March and September, and solstice months June and December. The curves are based on data from 1966 to 1979. The step curves represent data (average, maximum and minimum values). The smoothed curve is a fit to the average data (Hansen et al., 1981).

September, and solstice, June and December. As one would expect, the net radiation tends to be positive during the day while it tend to be negative during the night. However, the figure shows that winter days exist with negative net radiation during the whole diurnal cycle, while in summer there are nights where the net radiation tends to stay, if not positive, then at least very close to zero.

In conclusion of this discussion of net radiation it should be pointed out that the netradiation depends on the character of the underlying surface. Figures 2.3 and 2.4 are obtained over a grass area (i.e. grass during the summer). Furthermore, they describe fairly well the behaviour of net radiation over most "typical" Danish surfaces. However, for some surfaces, such as water and city areas some deviations must be expected from the figures.

The importance of the cloud cover in restricting the recorded sunshine hours is illustrated in Figure 2.5, which shows the relative distribution of sunshine in Denmark. The map is consistent with an average picture of the Danish climate, where winds from the west and southwest bring humid air over the country. Over land this air undergoes lifting and convection giving rise to an increase in clouds cover; this in turn results in relative minima of sunshine hours in the centre to the western parts of the larger land areas.

In Table B2 more information about sunshine and cloud cover is summarized (rows 13-25). As a consequence of the above-described variation of cloud cover across the country the statistics of sunshine hours for Bornholm, the most easterly position of Denmark, are displayed separately. It is further seen that in Denmark one may expect 1-5 clear days per month while a third of all days can be expected to be cloudy (clear days means an aver-average cloud cover of less than 20% of the sky, while cloudy days are days with an average cloud cover larger than 80%). On the average about 64% of the Danish sky is covered by clouds with the lowest values around 50% in summer and the highest around 75% in winter.

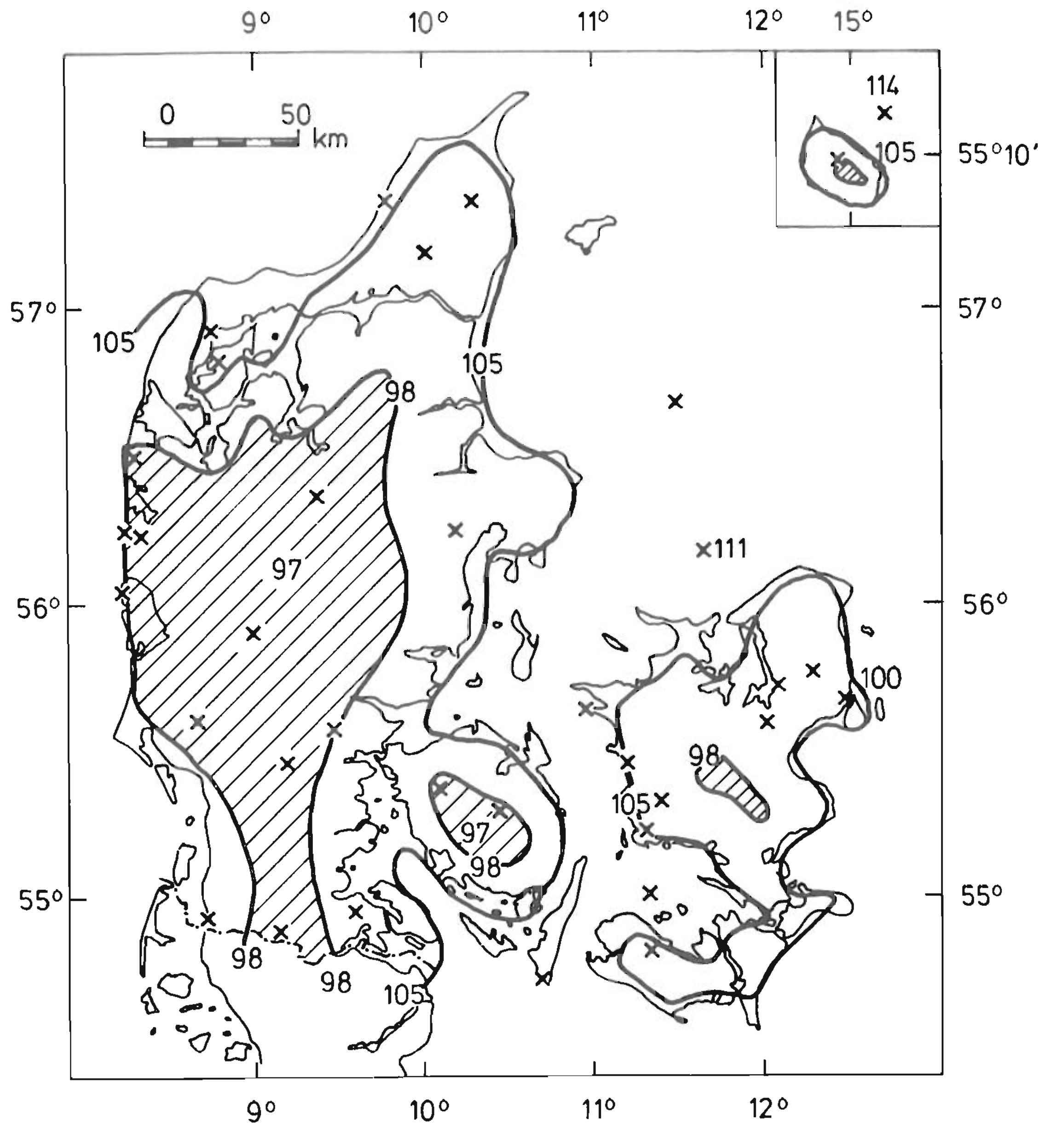

Fig. 2.5. Distribution of hours with sunshine in Denmark, relative to those measured at the Meteorological Institute in Copenhagen (in per cent). X indicates observation sites. The data used are yearly averages for the period 1961-71, (Teknologisk Institut, 1978).

3. PRECIPITATION AND RELATED PHENOMENA

In Denmark the average yearly precipitation is 660 mm/year. This is the nominal value pertaining to the period 1931-60. This figure may be about 16% too low as shall be discussed later. The monthly precipitation, both average and extreme values, are shown in Figure 3.1. The precipitation is generally seen to be at a minimum in early spring, with 30 mm in March and at a maximum in the late summer and with 80 mm in August. The variability around the normal values is seen to be fairly large, even to the extent that several times the monthly normal values can fall at a single station in 24 hours. Precipitation occurs in slightly less than 50% of the days of the year, while a large precipitation (larger than 10 mm/day) occurs only in 1-2 days per month, (see Table B3 and B2, row 35 through 41). Figure 3.2 shows the yearly variation of precipitation days, and, not surprisingly, this variation is seen to follow the variation in Figure 3.1 closely.

The curves in these two figures reflect the seasonal difference in the weather pattern and together they provide the following picture: In winter (December) the precipitation is moderate (50 mm/month) but occurs on the average during 16 days of the month of which only one gives more than 10 mm. The weather is dominated by passing frontal systems, a fact which agrees with the large cloud cover of 75% observed during this season (see Figure 2.1). Occasional high pressure systems with associated cold air outbreaks may result in some convective activity but these events are rare.

In the summer the precipitation is maximum (80 mm/month) but occurs on the average during only 14 days of the month. About three of these days, on the other hand, give more than 10 mm. This is associated with convective activity and occasionally thunder showers (see Figure 3.2). The frontal passings are less frequent than during winter and the sky is less clouded (50%). That the precipitation during summertime is associated with

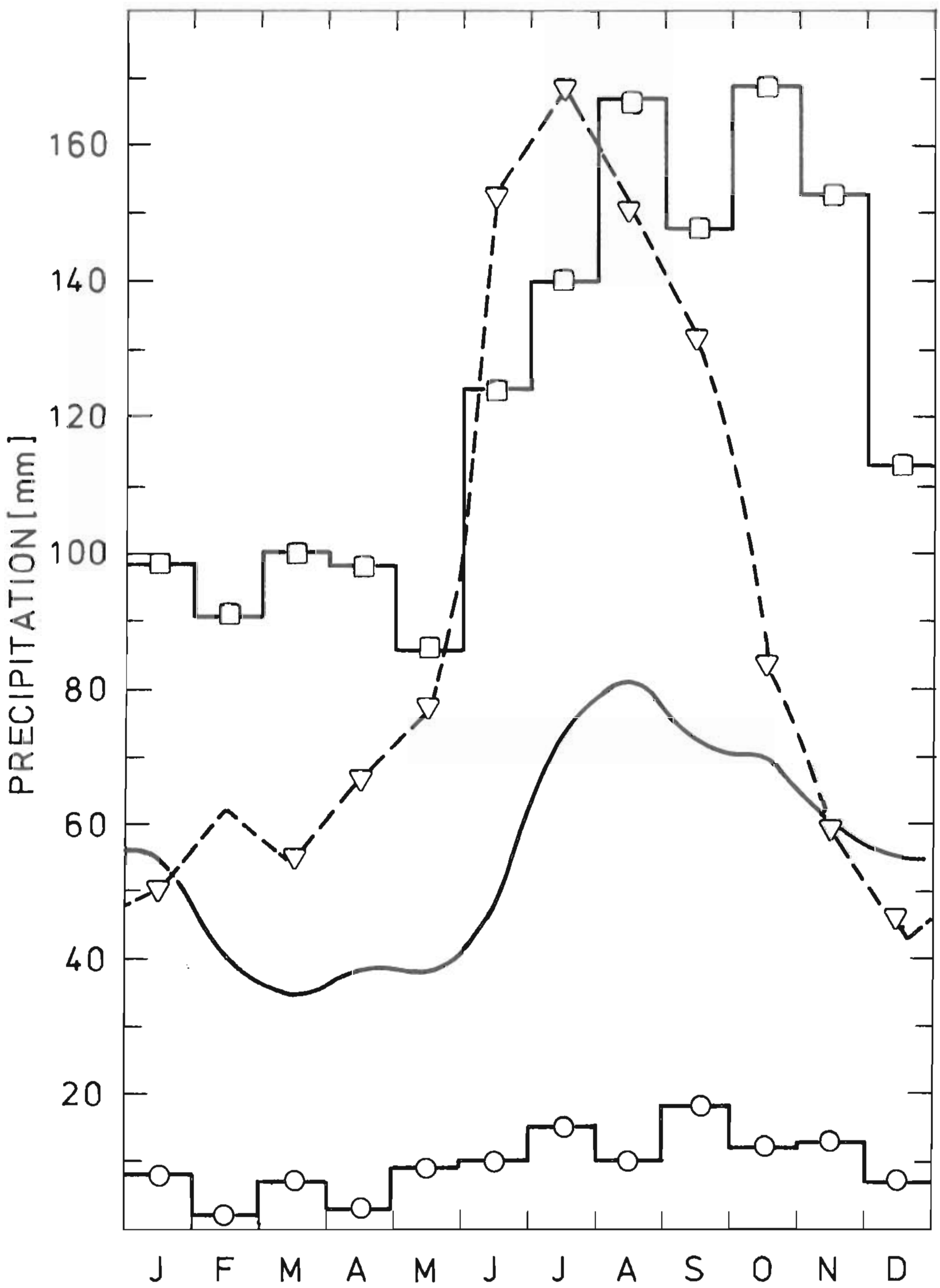

Fig. 3.1. Precipitation statistics for the months of the year.——: Normal monthly precipitation (1931-60) for Jutland and the Isles.-□-: Maximum (-O- minimum) recorded national averages (NA) of monthly precipitation for the period 1874-1978, -▽--: Maximum precipitation recorded over 24 hours at one of the stations in the period 1874-1978. The Figure is based on Table B2 rows 35-41.

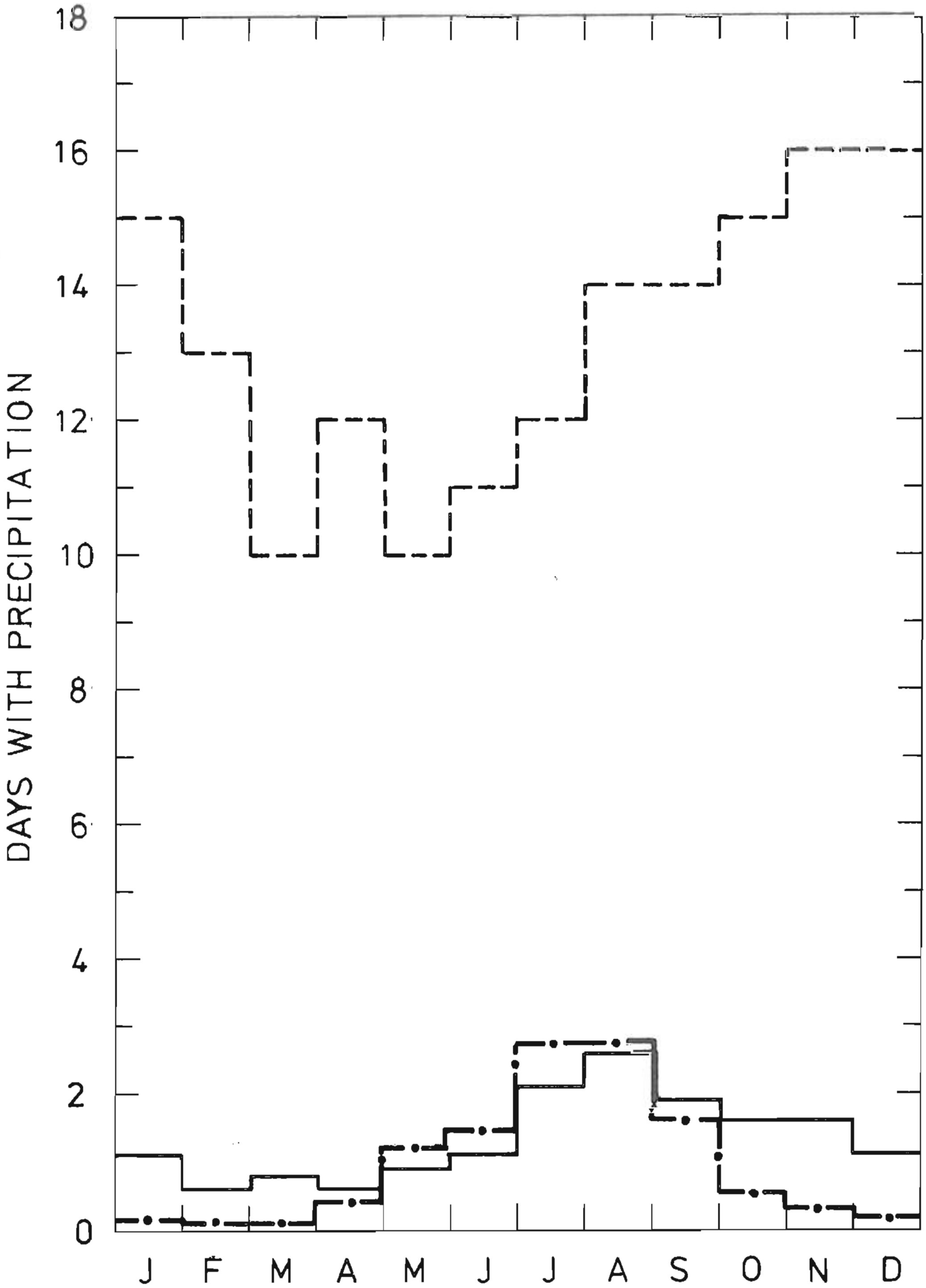

Fig.3.2. Days with precipitation.—•: Days with large precipitation (in excess of 10 mm/day). ---: Days with precipiation (in excess of 0.1 mm/day). -•-: Days with thunder. The figure is based on Table B2 rows 32 and 39-40.

convection is also consistent with the curve in Figure 3.1 showing the largest amount of precipitation that has occurred during 24 hours. This curve has a strong maximum centred around July.

Statistics of precipitation intensities over time spans shorter than a day have not been analyzed much in Denmark, although one study indicates that it rains in about 10% of the hours of the year (Gyllander and Widemo, 1980). The same study further indicates that the precipitation exceeds 10 mm/hr only twice every year, see Table B3.

For information about precipitation rates over shorter time spans we shall further appeal to the study by Jones and Sims (1978), where data series of precipitation rates over 1 and 4 minutes have been compiled from measuring stations over the entire northern hemisphere. Figure 3.3 shows their results for the precipitation rates versus frequency of occurrence for the different climate types. Since Denmark has a maritime temperate climate, it appears from their figure that precipitation should be expected to occur 10% of the time. This agrees with Tables B3 and B4. Further, the figure shows that the probability of precipitation rates larger than 1 mm/hr decreases very rapidly with increasing precipitation rate, e.g. 80 mm/hr will be experienced only once per century. This value is comparable to the highest precipitation rate measured in Denmark in 100 years, 280 mm/hr, measured as 70 mm in 15 min. (see Section 6). The daily variation of the precipitation has been described in Lysgaard (1968). He concludes that during the winter months most of the precipitation occurs at night, while most of the summer precipitation taken place during the day, reflecting the larger role of convection-induced showers in the summer period, as discussed above. That precipitation during the winter falls mostly at nighttime is consistent with the independence of frontal passages with respect to the diurnal cycle, and that the number of nighttime hours are predominant during the winter.

The geographical distribution of the precipitation in selected months and for the year is shown in Figure 3.4. The general pattern is seen to be much the same throughout the year, and re-

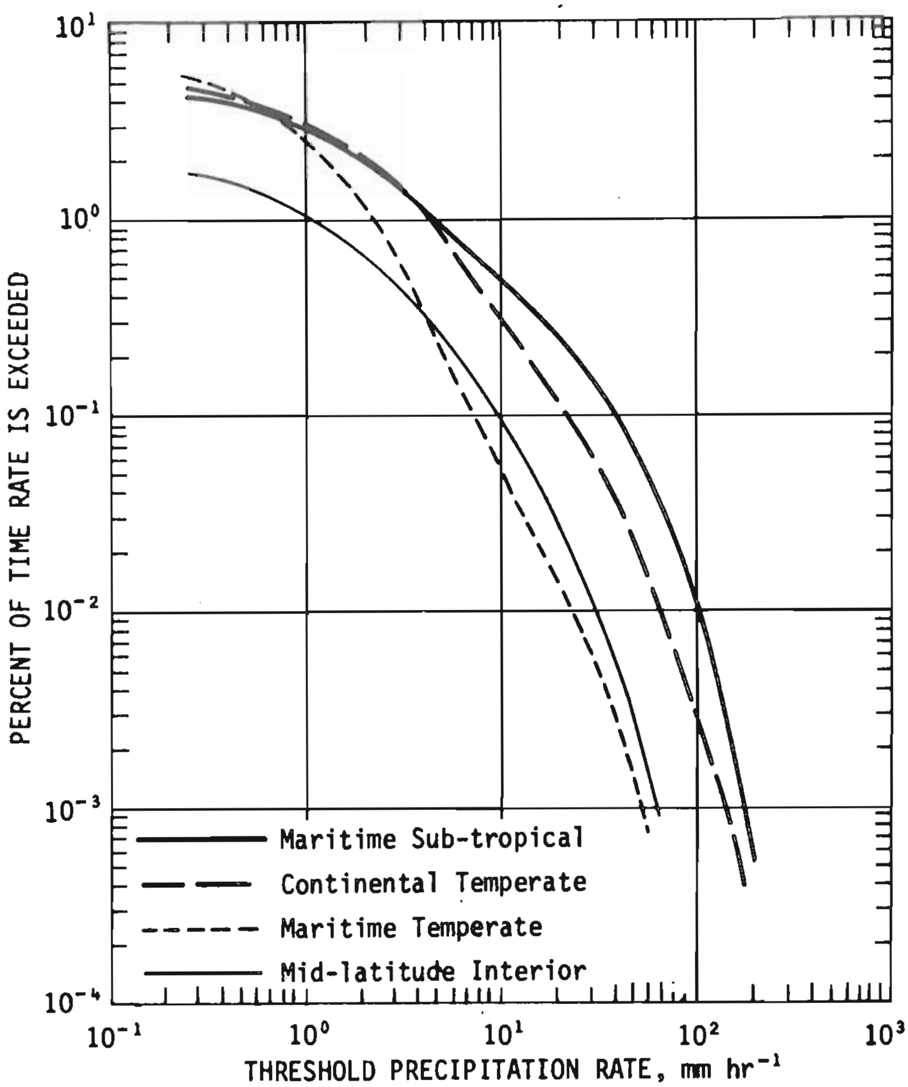

Fig. 3.3. Average precipitation intensity (over 1 min. and 4 min. but given as mm/hr) versus frequency relationship for four different climate types (Jones and Sims, 1978).

flects the observation that on the average the moisture comes from the west.

The correlation between the daily precipitation at a number of measuring stations in Jutland and the Isles have been studied in Hansen et al. (1970). A precipitation field will cover the whole country during 24 hours, understood such that the correlation coefficient, for the amount of precipitation measured the same day at any two stations in Denmark, is larger than 0.5. On the other hand there is only little correlation (coefficient less than 0.2) between the daily precipitation on one day and

MEAN PRECIPITATION 1931-60

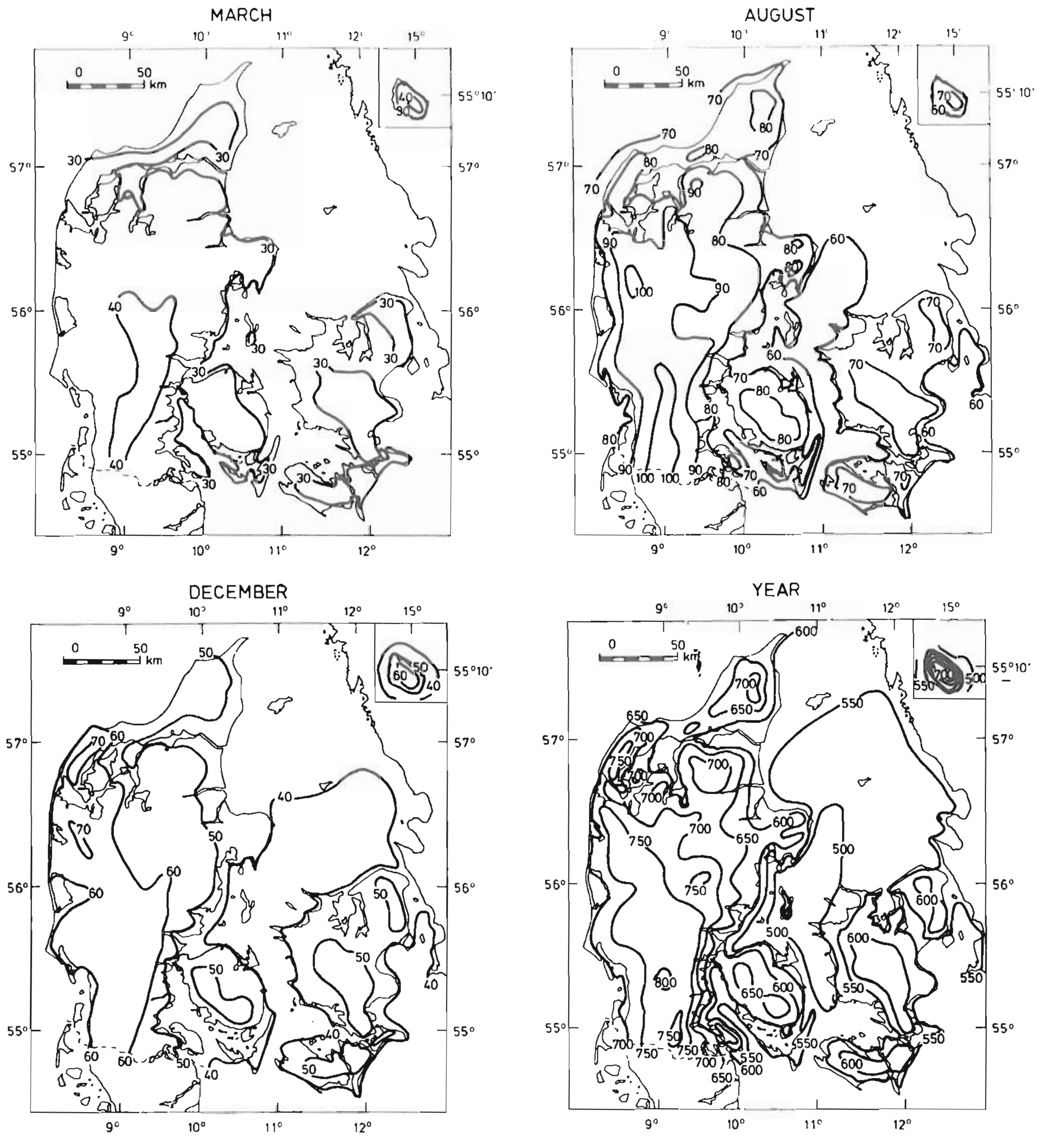

Fig. 3.4. Geographical distribution of the precipitation in Denmark for the months of March, August and December, and for the whole year, based on the period 1931-60 (The Danish Meteorological Institute, 1975). March is the month with the least precipitation, August with the most and December with close to the yearly average.

the next, irrespective of whether we are correlating measurements from a single measuring station or different ones.

Precipitation takes many forms. In Copenhagen Airport in Kastrup observation of the different forms of precipitation have been performed every half hour since 1949. The results for a twenty-year period were compiled in Table B4. For example, it is seen from this table that it rains between 6 and 16% of the time with a maximum in November and minimum in February; on the other hand in February snow frequency is a maximum for the year (10% of the time). So far we have been referring to amounts of precipitation which have been measured by standard rain gauges, and which are obtained from standard climatological tables such as is found in Tables B2 and B3. Recently, it has been shown that these rain gauges underestimate the amount of precipitation falling on the ground by about 16% in Denmark, as mentioned in the beginning of this chapter. The reason for this error is mainly flow deformation around the rain gauge. The study resulting in this conclusion is described in Allerup and Madsen (1981), from where we have taken Table B5, which shows the monthly precipitation value pertaining to the period 1931-60, both before correction (corresponding to Table B2 row 36) and after.

From this table it is seen that a better estimate of the annual precipitation might be 770 rather than 660 mm. These corrections, however, have so far not worked their way into the official climate statistics for Denmark; for this reason we kept the original estimates from Table B2 and Figures 3.1-3.4. Further,if comparison with precipitation values of other countries is of interest, it must be borne in mind that these values might have to be corrected correspondingly.

Snow, sleet, and hail

It is difficult to estimate the proportion of the precipitation that falls as snow, hail, or sleet. The amounts associated with these types of precipitation are not measured directly. However, in a limited study reported by Allerup and Madsen (1981) the distribution between liquid and solid precipitation is estimated (see Table B6). In January, February and March little more than 40% of the precipitation falls as solid particles, in December the percentage is 24, while April and November each has about 5% solid precipitation.

As indicated above, Denmark has six months of snowfall. The frequency of occurrence can be found in Table B4. In January and February it snows about 10% and in November and April about 1% of the time. Sleet is seen to be distributed similarly with a maximum frequency of 2% of the time. Additional information on the snowfall is found in Table B2 row 33 and 34, which describes the number of days per month where snowfall has been observed (row 33) and the number of days with snow cover of the ground at 8 a. m. (row 34). It appears that it snows 25 days per year with a maximum of 7 days in January, while snow cover is observed at 42 days per year again with maximum in January and February (12 days each). Further, the geographical distribution of days with snow cover is seen in Figure 3.5. Not surprisingly, this distribution appears as a compromise between the precipitation and the temperature distribution in the winter period, (see Figures 3.4 and 4.5). Finally, Table B4 shows that hail is a rather unimportant phenomenon in Denmark with an average maximum frequency of 0.1% of the time in March.

Fog and drizzle

Table B4 shows that fog and drizzle also occur most often during the winter (in total about 10% of the time). From May through September the frequency is reduced to around 1%.

Figure 3.6 shows the variation during the year of the water vapour pressure, which is seen to vary in phase with the changes of the temperature (see Figure 4.1). The reason for this correlation between temperature and water vapour pressure is that the saturation pressure for water vapour in air is an increasing function of the air temperature. This saturation pressure is the maximum partial vapour pressure that the air will sustain at a

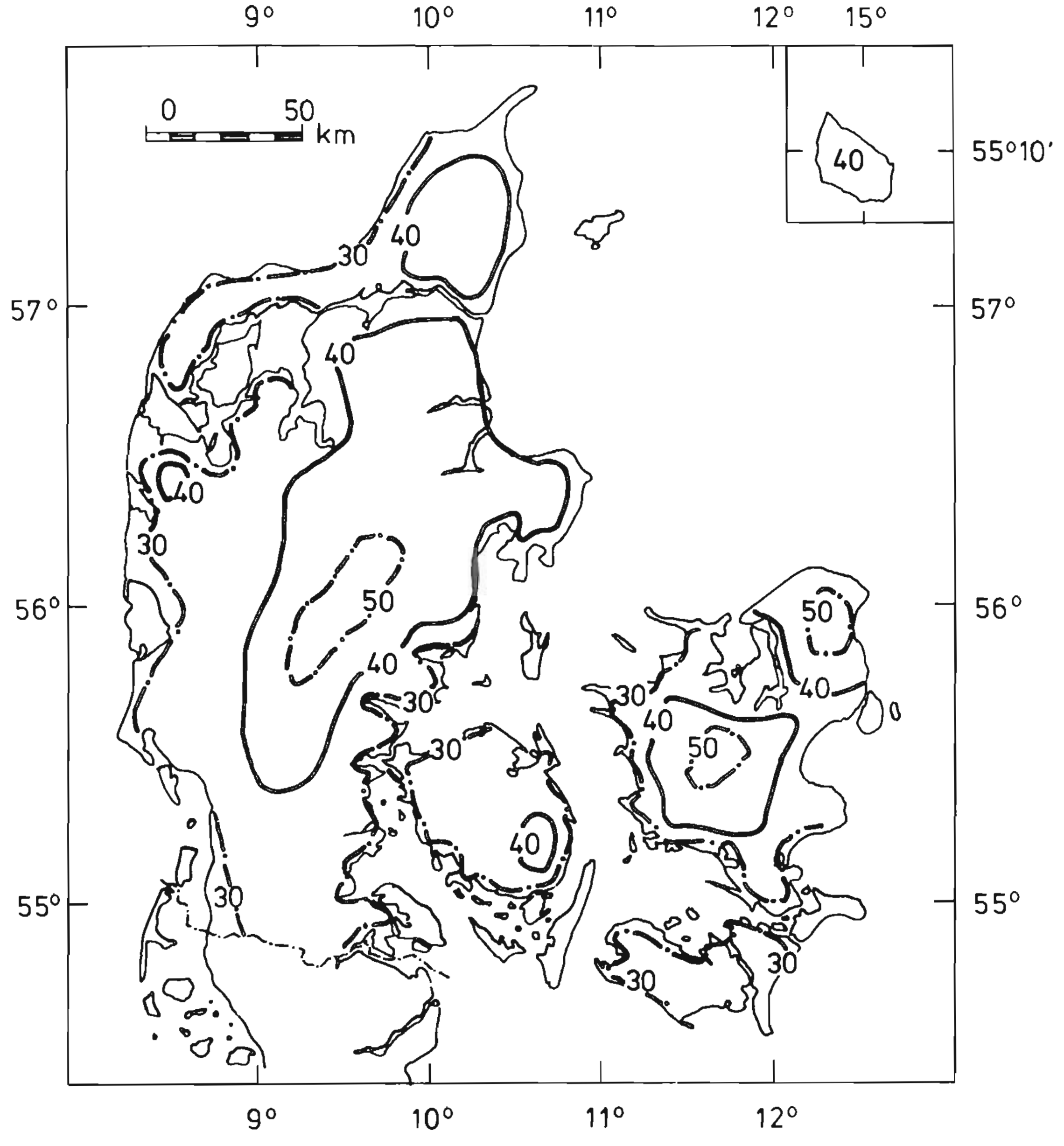

Fig. 3.5. Geographical distribution of days with snow cover in Denmark. Recorded in the period 1956/57-1970/71 for the months November-April (Madsen and Allerup, 1975).

given temperature in otherwise clean air; hence the saturation pressure is a measure of the air's capacity to hold water.

Further, Figure 3.6 shows the yearly variation of the relative humidity, which is the water vapour pressure relative to the saturation vapour pressure. The relative humidity in Denmark is seen to be fairly high over the year (82% in the average).

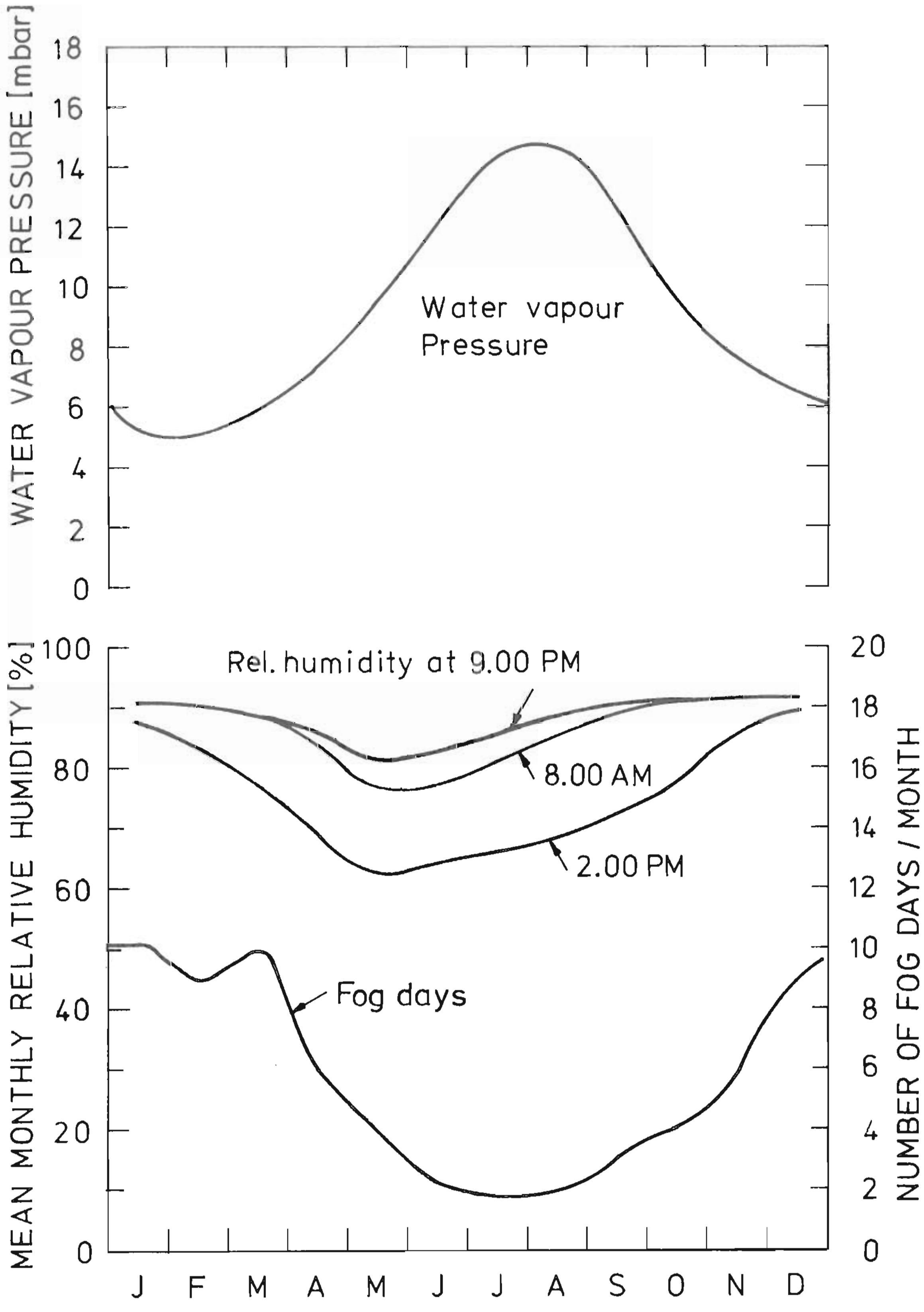

Fig. 3.6. Yearly variation of the number of fog days per month, of water vapour pressure, and of relative humidity. The curves are based on Table B2, rows 26-31.

It is interesting to note that the daily average of the relative humidity is low during the summer despite the increased level of the water vapour pressure during this period. This can be deduced from Figure 3.6 and seen directly from Table B2 row 26. The reason for this is indicated by the daily variation of the relative humidity, as shown in the figure. As the day heats up, the evaporation cannot increase rapidly enough to keep the water vapour pressure in equilibrium with the increasing saturation pressure, and consequently the relative humidity drops. During the nighttime cooling, the saturation pressure decreases, and the water vapour, that has been absorbed by the air during the day, condenses. The mechanism ensures that the daily average of the relative humidity will be lowest during the summer, where the duirnal temperature variation is largest (see Figure 4.1). Indeed Figure 3.6 indicates that throughout the year the dialy average value of the relative humidity is limited by the night temperature, and that the relative humidity at night is constant (~ 90%), irrespective of the season.

Finally, Figure 3.6 shows the yearly variation of the number of fog days per month. (A fog day is one in which the visibility due to fog is less than one kilometer for some part of the day). On the average about 5 days per month can be characterised as fog days. It is seen from the figure that actually we have two distinct levels: During the summer the number of fog days is 2-4, while at wintertime it is 8-10.

As expected, the yearly variation of fog days does correlate fairly well with that of relative humidity. During summer and fall fog is mostly associated with nighttime cooling, while during winter and spring it is mostly connected with advection of warm air masses over colder surfaces. This last phenomenon is especially important during the spring and early summer, where warm and humid air is advected over the Danish coastal waters, which are still fairly cool. The fog in that period is often located to the coastal areas while at the same time the inland areas experience warm and sunny weather. It should be noted that the curve for fog days in Figure 3.6 represent national average values and hence describes an average of observations from inland and coast stations.

Thunder and lightning

Thunder occurs in all months although with maximum frequency in the summer (0.4% of the time, Table B4, or 2-3 days per month, Table B2, row 32). For yearly variation of days with thunder see also Figure 3.2.

The geographical variation of the lightning frequency is shown in Figure 3.7, which is based on measurements of lightning flashes for the years 1965-1977). The figure shows the geographical distribution of the average yearly number of lightning flash counts as well as the average yearly number of days with more than 5 counts/day. It is seen that the lightning frequency is highest in southwestern Jutland with a tendency towards a local maximum around Copenhagen. By comparing Figures 3.4 and 3.7, it is seen that the lightning distribution follows fairly accurately

the pattern for the geographical distribution of the precipitation, illustrating that the phenomena are related, and that convective activity plays a strong role for both phenomena as is also illustrated in Figure 3.2. More information concerning the yearly variation of thunder and lightning is given in Table B7. This Table indicates that for the 20 year averaging time considered here, the standard deviation around the average number of monthly lightning flash counts approximately equals the mean value, indicating how variable is the presence of thunder and lightning from year to year. The same kind of variability for the amount of monthly precipitation is noted in Figure 3.1, and it can probably be assumed to exist for all precipitation related phenomena.

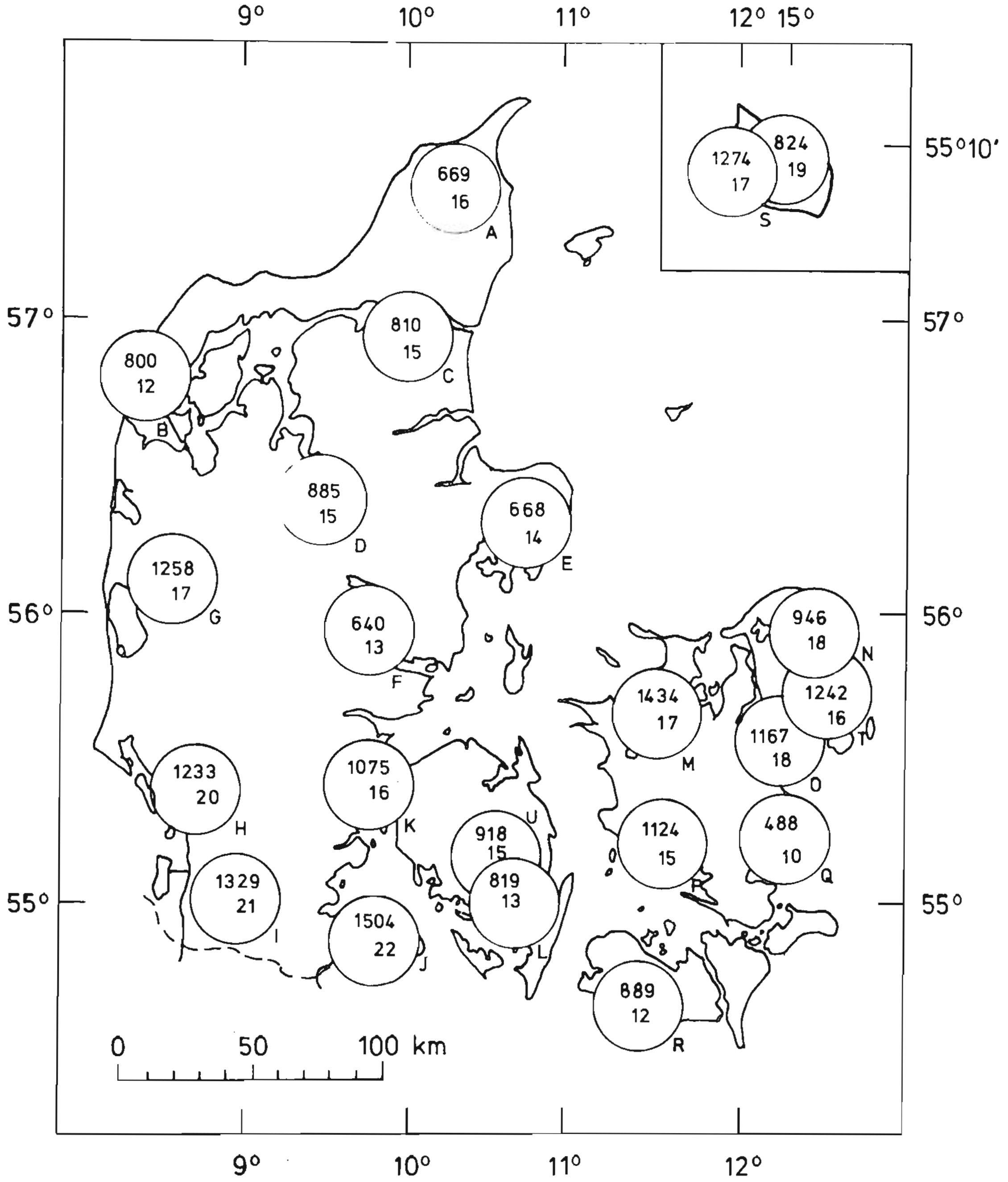

Fig. 3.7. Geographical variation of the number of lightning flash counts per year as recorded by Naver (1965-1977); the upper number in the circles shows the average number of counts per year, while the lower number indicates how many days have more than 5 counts. The instruments are placed in the centre of the circles and they have a detection range roughly corresponding to the periphery of the circles (100 km^2).

4. TEMPERATURE

As a result of the yearly and diurnal cycles, the temperature in Denmark may vary considerably. As an upper bound on the temperature variability, it can be mentioned that for the last 100 years the difference between the highest and the lowest measured temperature is 67°C.

Figure 4.1 gives an impression of the yearly variation of temperature in Denmark as well as of the total variability. Further information is found in Table B2, rows 1 through 12, and in Figure 4.2.

It is seen that any month has a risk of sub-zero temperatures; however, only January and February have average temperatures below 0°C (-0.1 and -0.4°C, respectively). Figure 4.2 indicates that in average the temperature in December and March stays below 0°C (icedays) approximately 3 days per month, while the number for either January and February is about 9. The number of days in which the minimum temperature drops below 0°C (frost days, which usually means frost at night) is, of course, more widely distributed with about 20 days in January, February, and March; they may be expected in May and September as well.

One of the results of a lengthy frost period is the formation of ice in the Danish waters. Table B8 presents a summary of the number of days with severe ice conditions in Øresund, Storebælt, and Lillebælt in the period 1908-72. It is seen that roughly 1 year out of 4 is characterized by severe ice conditions.

In the warm end of the scale, June, July and August has as an average about 3 days each with maximum temperature higher than 25°C ("summer" days) and such days occur in May and September as well.

The character of the diurnal cycle of the temperature does, of course, vary with the time of the year. Based on 10 years of

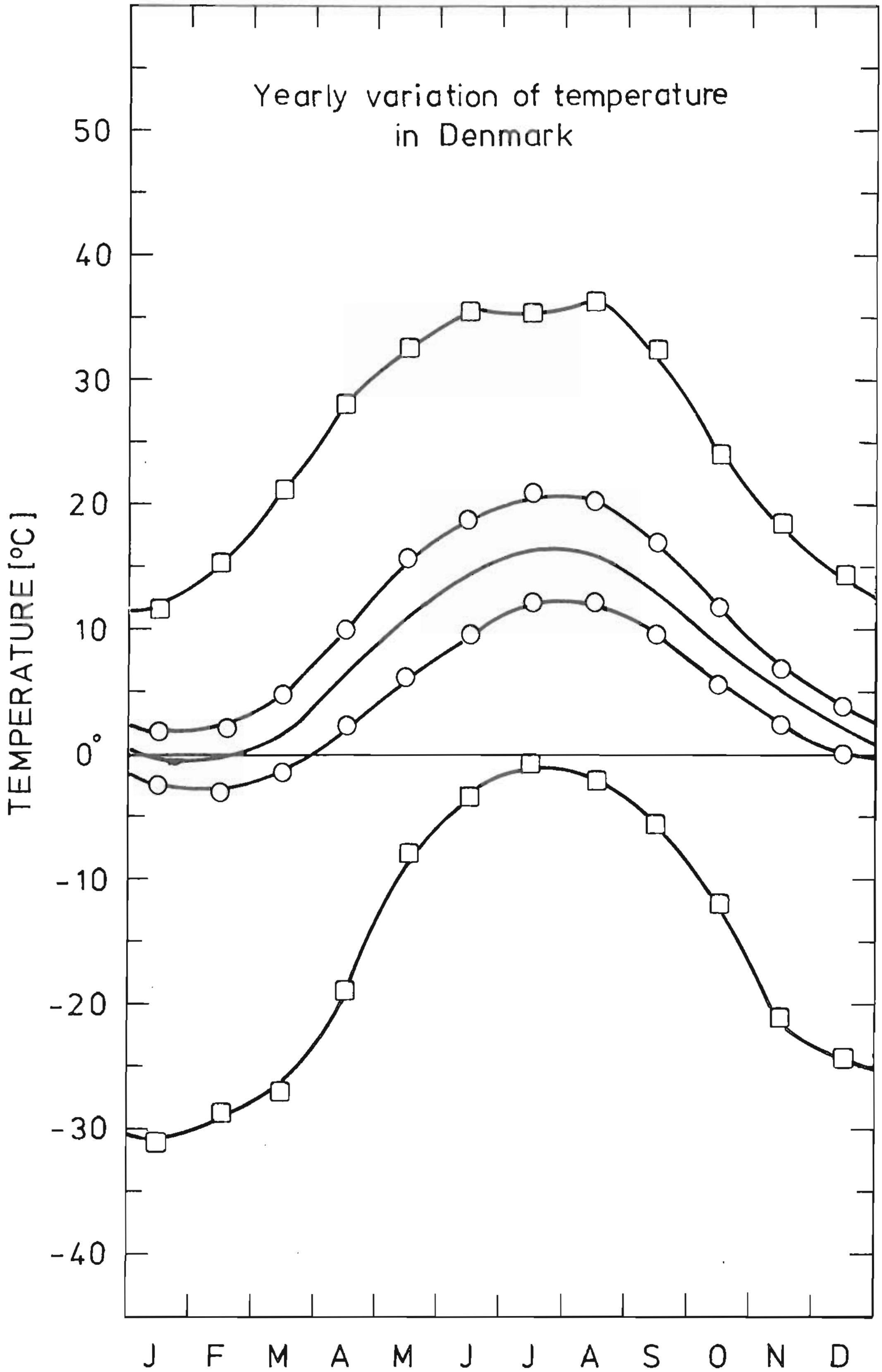

Fig. 4.1. Yearly variation of different monthly temperature indicators for Denmark.—— : Normal temperature for the period 1931-60; -o- : Average monthly maximum (minimum) temperature for the same period. —□— : Absolute maximum (minimum) temperature as measured at any station in the period 1874-1978. The data are taken from table B2, rows 1 through 9.

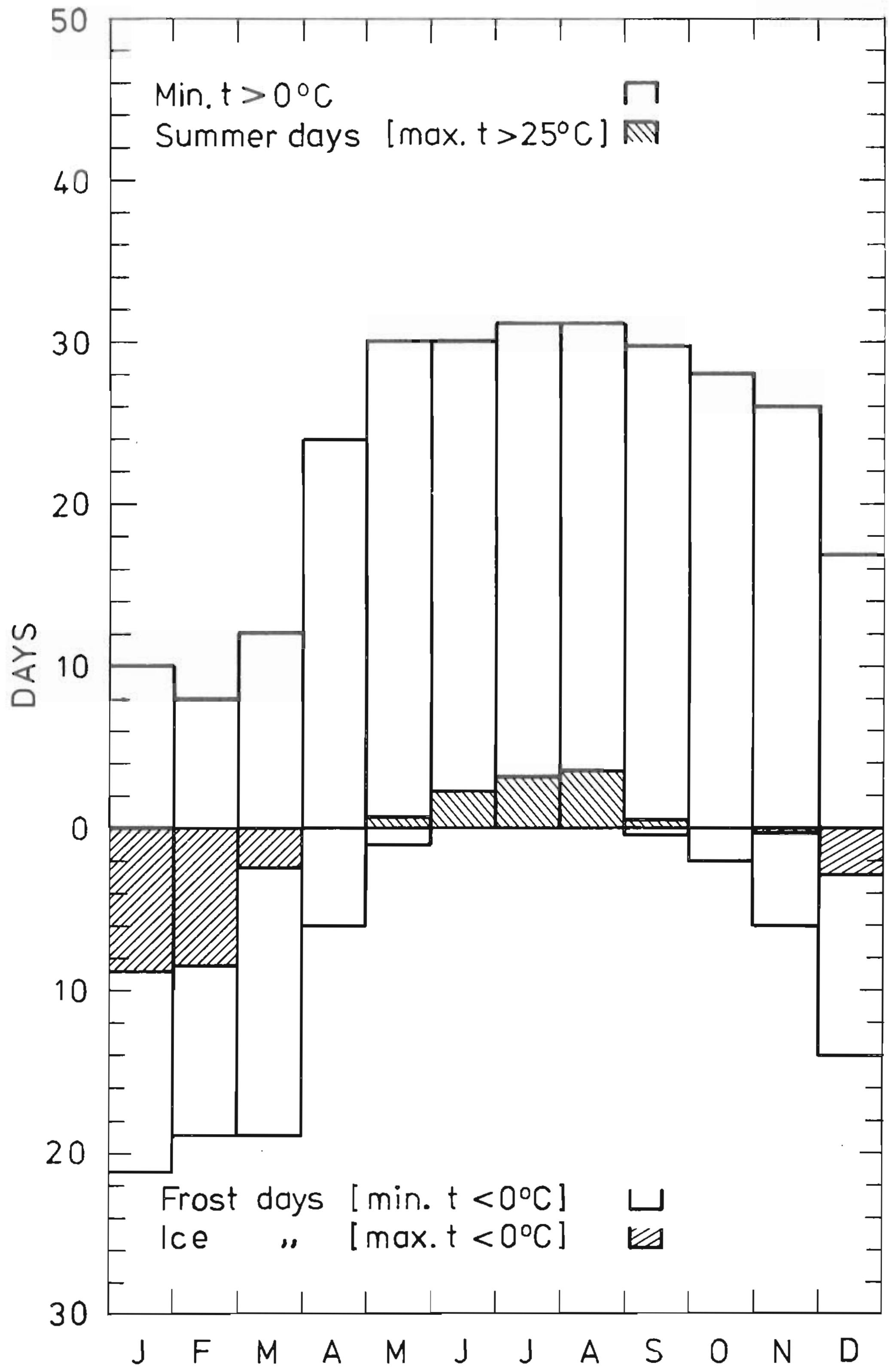

Fig. 4.2. Average monthly number of ice days, frost days, and days for which the minimum temperature is above 0°C, and days for which the maximum temperature is above 25°C. The data are taken from Table B2, rows 10-12, and pertain to the period 1931-60.

data from Risø, Figure 4.3 shows the average daily variation of temperature in the lowest 127 meters of the atmosphere for the equinoctial months (March and September) and solstice months (June and December), respectively.

Fig. 4.3 shows that the daily variation of temperature is larger during June than December. This is related to the greater insolation, the longer days and the lessened cloud cover during summer, as discussed in Section 2. At a height of 2 meters the average diurnal variation is about 5°C in June and 0.5°C in December.

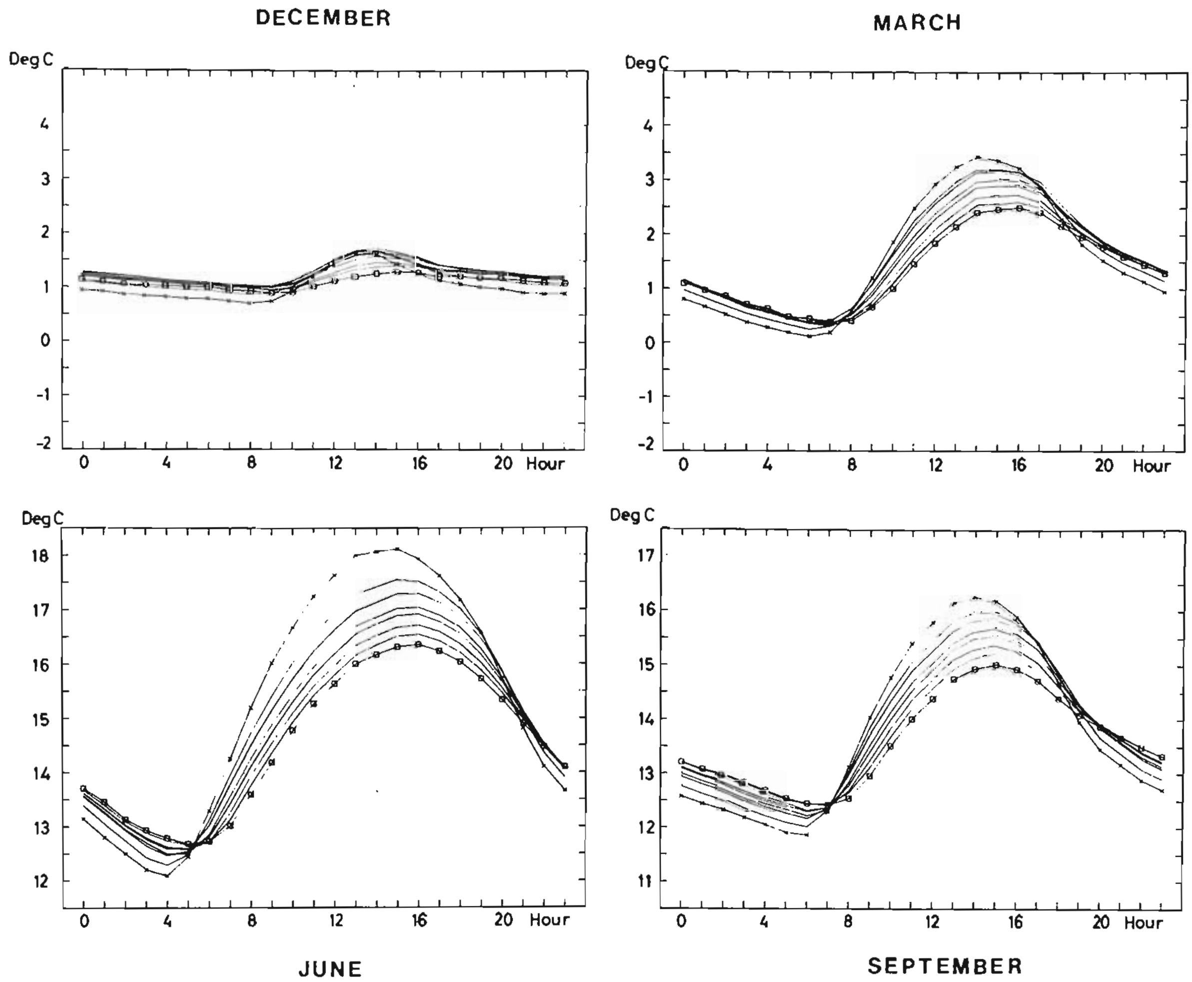

Fig. 4.3. Average daily temperature variation at the heights 2, 7, 23, 39, 56, 72, 96,and 123 meters above the ground for the solstice and equinoctial months (June and December, and March and September), respectively. The 2-m level is indicated by -✕-, and the 123-m level by -⊟-. The curves represent averages over 10 years (1958-67) (data from Risø and the figures are taken from Petersen (1975)).

The seasonal variability of the daily changes of the air temperature is shaped by a number of factors. As the solar radiation heats up the soil, the heat is transferred to the air by conduction from the surface; further up in the atmosphere transfer takes place by turbulent mixing. This influence reaches the higher altitudes the more intense is the insolation. On a summer day the boundary layer reaches a height of several kilometres. (the boundary layer is the layer of the atmosphere, which feels the presence of the surface directly). At night, on the other hand, the surface loses heat by long-wave radiation. This causes a cooling of the soil. By turbulent mixing this cooling is transferred to the lower layers of the air. The nocturnal boundary layer this way created is much more shallow than the daytime one, the former being typically 100 m.

Also, other factors are of some importance as can be seen by considering the figures for the equinoctial months, March and September. Here the length of the days, and the solar elevation are equal. However, the average daily temperature variation is clearly somewhat larger in September than in March. In September the diurnal variation is about 4°C at the 2-meter level while it is 3°C in March.

There are several important reasons for this asymmetry:

1) In March the soil is very wet, and partly frozen, and snow-covered (see Table B2, row 34) causing a fair amount of the incoming solar radiation to be either reflected, or used to evaporate water, or melt snow and ice without increasing the soil temperature. Conversely at night part of the heat loss is compensated by freezing of some of the water. The associated release of latent heat reduces the lowering of the temperature.
2) The total incoming radiation itself is slightly smaller in March than in September. This is caused by a slightly larger cloud cover during March (60% compared to 55%), and also by a slightly greater turbidity during March.
3) The annual cycle causes conditions in March and September to be basically dissimilar as the soil in the spring heats up

and in the fall it cools down. Assuming a sinusoidal variation in the surface temperature, the solution to the heat conduction equation for the upper soil layer yields the result that the heat flux to and from the soil is $\pm\, t_o \sqrt{\pi \rho c \lambda / \tau_o}$ at the time of the two equinoxes, the positive sign referring to spring (t_o is the amplitude of the temperature oscillation considered; ρ, c, λ the density, heat capacity, and heat conduction of the soil; τ_o the oscillation period, i.e. one year). With this formula and relevant values of the parameters we get $\pm$ 3 watt/m^2. This agrees quite closely with the measurements depicted in Figure 4.4, where 3 watt/m^2 corresponds to a total daily soil flux of 0.25 MJ/m^2. As the daily average of total net radiation is only about 10 times that at this time of the year (i.e. 2.5 MJ/m^2, see Figure 2.3), the soil heat flux is a significant contribution to the heat budget. As such, it may be the more determining factor of the above mechanisms.

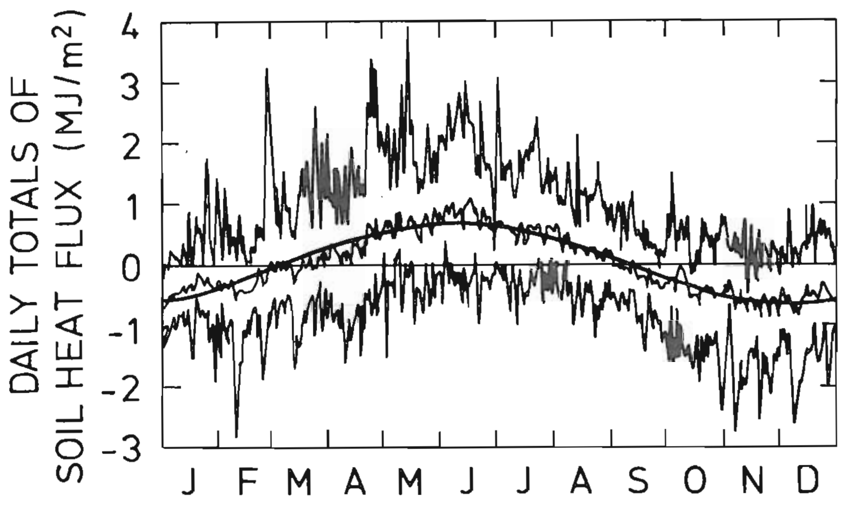

Fig. 4.4. The figure shows the seasonal variation of the total daily soil heat flux from the period 1966-1979. The center curve corresponds to the average value, while the upper and lower curves to the absolute maximum or minimum of the observed soil heat flux during the period considered. The smooth curve through the average data is a best sinusoidal fit (after Hansen et al. 1981).

This factor is also partly responsible for the delayed temperature maximum during the summer. The above solution to the heat conduction equation gives a phase lag of $\tau_o/8$. According to this, the temperature should be expected to top around the first of August well in accordance with observations (see Figure 4.1).

The same mechanism operates on a diurnal basis where heat is stored during the day and lost by radiation at night. In summer the amplitude in this exchange is of the order of 50 W/m^2, and the temperature is expected to top about 3 hours after solar noon (compare with Figure 4.3).

Finally, should be mentioned that the ocean of course influences the temperature of the air above or adjacent to the water. Therefore no discussion of the air temperature variation in Denmark can be complete without a description of the changes in the water temperature and its coupling to the air temperature. These phenomena are considered below.

The geographical variation of the air temperature is shown in Figure 4.5 for the coldest month, February, for May, where the region is heating up, and for August, just after and around the annual temperature maximum. Also shown is the yearly average isotherms.

The figure illustrates the moderating influence of the water (and here especially the North Sea) on the seasonal temperature variation. In the period where the region heats up it generally gets warmer at points inland and towards the east, while in the cooling period, and especially during the winter, inland regions in an easterly direction become colder. As expected, however, the temperature variation across Denmark is fairly small; for all subfigures in Figure 4.5 the warmest and the coldest isotherm differ by only 1-2^oC.

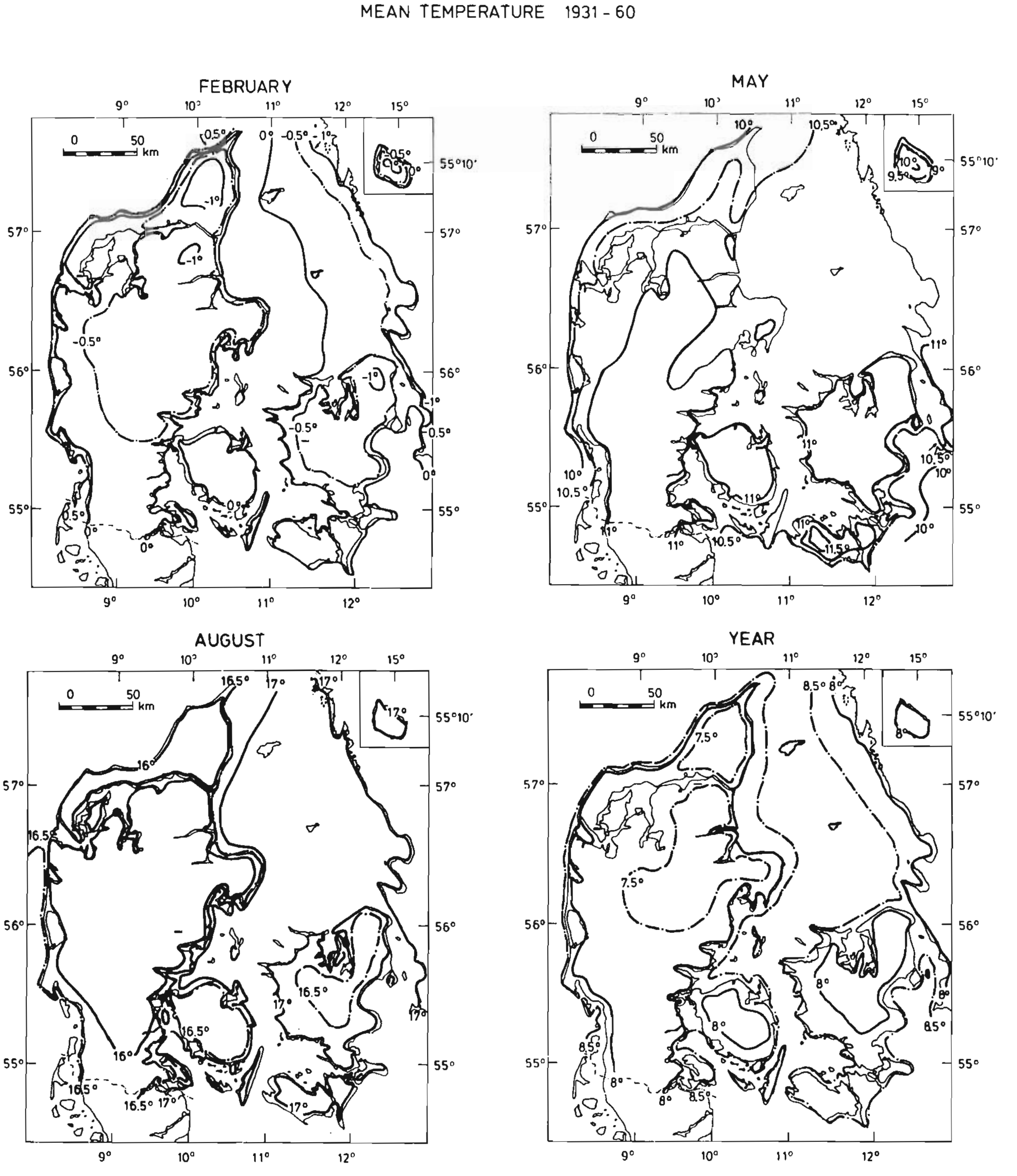

Fig. 4.5. Normal (1931-60) isotherms for February, May, August, and for the year. The figures are taken from Danish Meteorological Institute (1975).

Sea surface temperature

As mentioned in connection with Figure 4.5, water will generally modify the air temperature variations induced over land. The differences between absorbtion/emissivity and other thermal properties for typical land and water surfaces causes the temperature of the two surfaces to vary differently. The differences in surface temperature in turn are communicated to the air above by turbulent mixing, as is described above. Therefore the air temperature at a given place will to a large extend depend on the origin of the air. Hence, one finds geographical variations of the air temperature as depicted in Figure 4.5. It should be pointed out though, that with the given distribution of land and water in Denmark the average air temperature anywhere in the country will to a larger or lesser extend be influenced by the nearness of the water.

Compared to a land surface a water surface has a number of efficient methods to oppose temperature changes:

a) Changes in the surface temperature is mixed downward by wave and or current induced turbulent mixing, which is a much more efficient transport process than the molecular diffusion process, that controls the heat transport below a land surface.
b) During the day water surfaces can avoid heating up because of the cooling effect of evapporation. If, in addition, the water is salty, the upper layers will be rich in salt, and thereby heavier than the lower and cooler layers, which consequently rise above it.
c) During the night the layer which loses heat due to surface radiational cooling will increase in density and thereby sink; consequently it will be replaced by warmer water from below.

As a consequence of these mechanisms it is necessary to heat/cool much more than just the surface of the body of water to have any lasting influence on the water surface temperature, as opposed to the situation for a land surface where heat transport below the surface as stated above is controlled by the much less efficient molecular diffusion processes.

Furthermore, the Danish waterways have their own heat supply from the warm Gulf stream that runs through the North Sea and into the Kattegat and the Baltic Sea.

Therefore it is not surprising that the surface water temperature will have a different seasonal and diurnal variation than the air temperature over land. Typically the duirnal variation of the water temperature is small, while the amplitude of the annual variations are about the same for the water and the air temperatures, with a tendency for a slight delay of the water temperature relative to the air temperature, a delay which in concert? with other mechanisms is responsible for the delay of the annual maximum of the air temperature relative to the annual insolation maximum, see the discussion on p. 20.

Figure 4.6 shows for the period 1931-60 the yearly variation of surface water temperature in Denmark compared with the corresponding variation of the air temperature taken from figure 4.1. The figure illustrates how the water acts as a heat reservoir during the fall and winter seasons where the land cools off. It is seen how the normal air temperature follows the normal minimum water temperature from September through December, suggesting that the duirnal mean of the air temperature in an average sense can not fall below the minimum water temperature. The figure further shows that the amplitude of the yearly variations are about the same, but that the air temperature shows larger variability than does the water temperature, in accordance with the more sluggish response of the water surface temperature to heat gains and losses.

In Figure 4.7 the isotherms for the sea surface temperature is shown for four characteristic months. It is seen that also the water temperature varies systematically with location, compare with Figure 4.5 for the air temperature: the temperature of the waters enclosed between Jutland and the Isles and Sweden exibits a somewhat larger annual variability than does the temperature of the more open water areas of the North Sea and the Baltic Sea. This is in accordance with the expectation that landlocked waters follow the overland temperature pattern more closely than

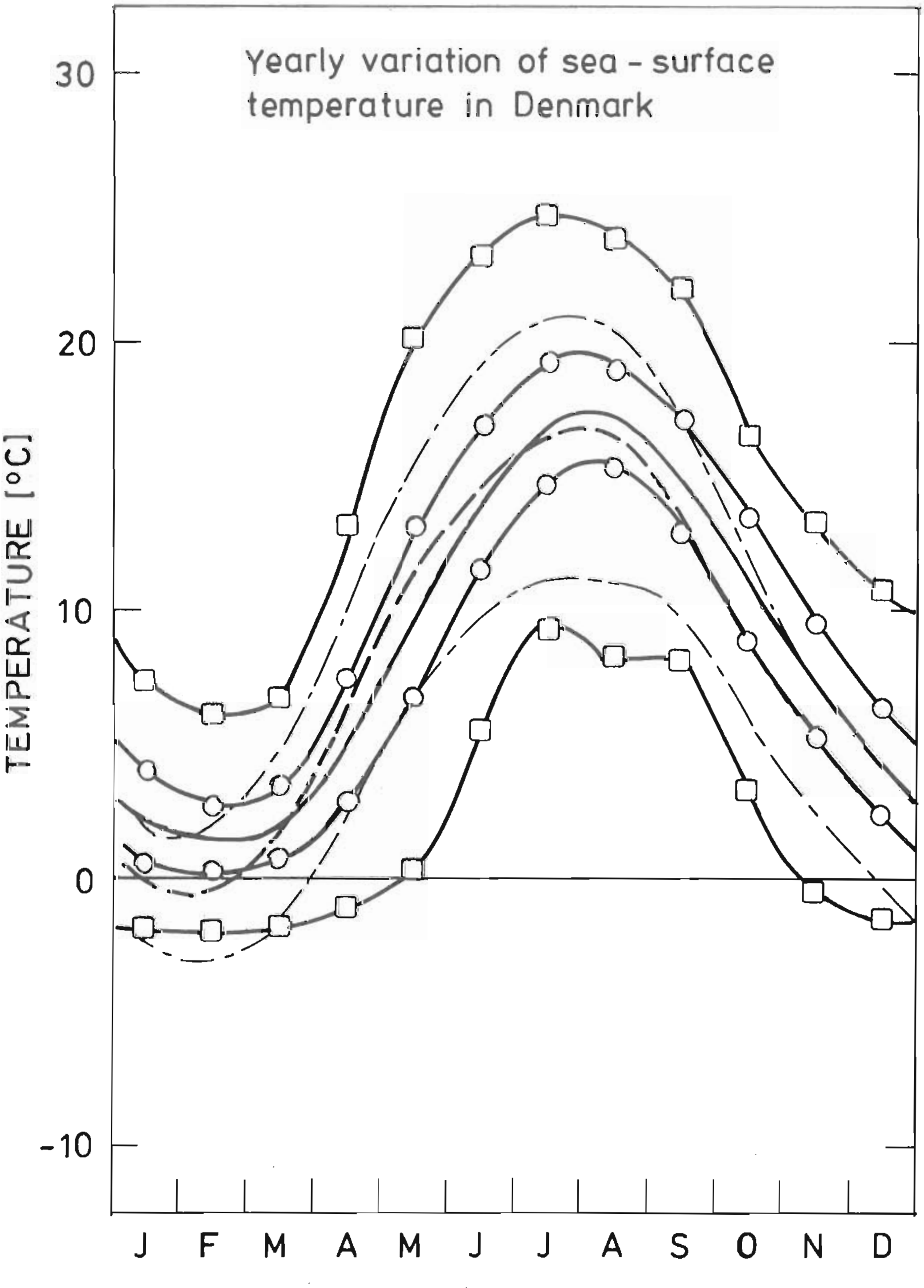

Fig. 4.6. Yearly variation of the sea-surface temperature in Denmark for the period 1931-60. —: Normal temperature; -O-: Average monthly maximum (minimum) temperature; —□—: Absolute maximum (minimum) temperature as measured at any station. The data are taken from Simonsen (1982) and are given in Table B13. Also shown are the temperature for air taken from Fig. 4.1; --: Normal temperature; -•-: Average maximum (minimum) temperature.

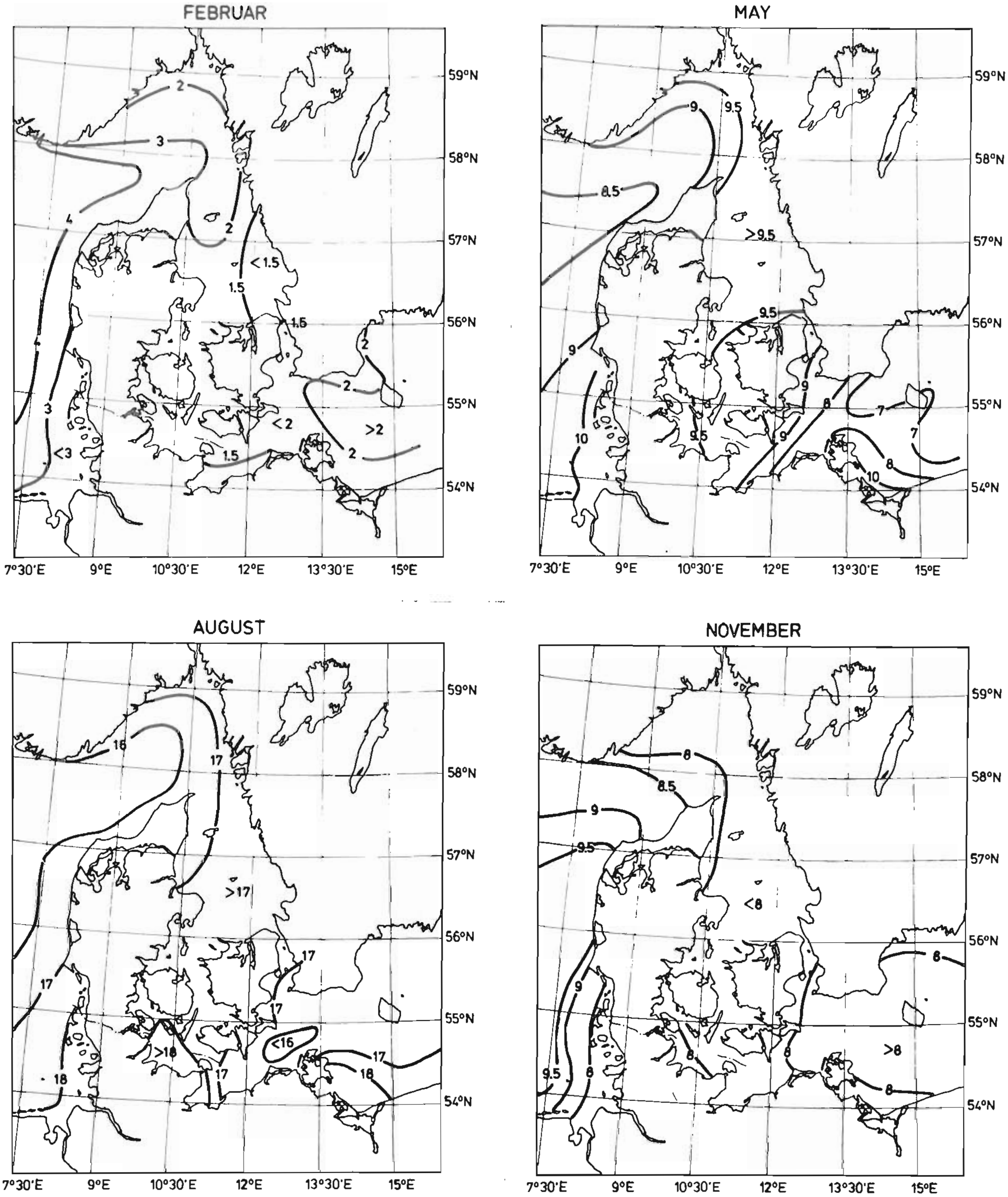

Fig. 4.7. Geographical variation of the sea-surface temperature for four characteristic months. The isotherm are composed from three different sources covering different time periods. 1931-60: Simonsen (1981), 1902-56: Lenz (1971) and 1905-54: Conseil International (1962). The isotherms pertain to relatively free water surfaces. Very close to land and for enclosed waters there is a fine structure in the isotherms which is not shown here.

open seas. Furthermore, the sea surface temperature is seen to follow the same trend as was discussed for the air temperature in connection with Figure 4.5, that the water gets warmer towards east in the warm season and conversely, gets colder towards east in the cold season.

From Figure 4.6 we may conclude that the monthly normal temperature of the sea surface is higher than the corresponding air temperature, except for spring where the land is heating up. This is consistent with the fact that a water surface generally is a more efficient absorber of sunlight than is a normal land surface. However, we raise a note of caution against too strict conclusions based on figures like Figure 4.6, recalling the comments about fuzziness in climate statistics made in the introduction. This argument can be illustrated here from Figure 4.6, where national average temperatures for the sea and the air are compared. Unavoidably, the averages involve two different networks of measuring stations. The resulting average values of course will depend on the position of these stations relative to the distribution of isotherms as shown on Figures 4.5 and 4.6.

If we concentrate on discussing the sea surface temperatures, in total 30 stations are involved in the averages (Sørensen, 1982). Of these stations 28 are placed in the inner Danish waters, very close to land or in the waters between Jutland and Sweden. Only two stations are on the borders between Danish waters and larger water areas: One in the North Sea and one in the Baltic Sea (close to Bornholm).

The position of these 30 stations seems sensible to yield an estimate of the Danish national average sea surface temperature. However, Figure 4.8 shows that the behaviour of this temperature would change somewhat if more stations from the North Sea and the Baltic Sea were included in the average.

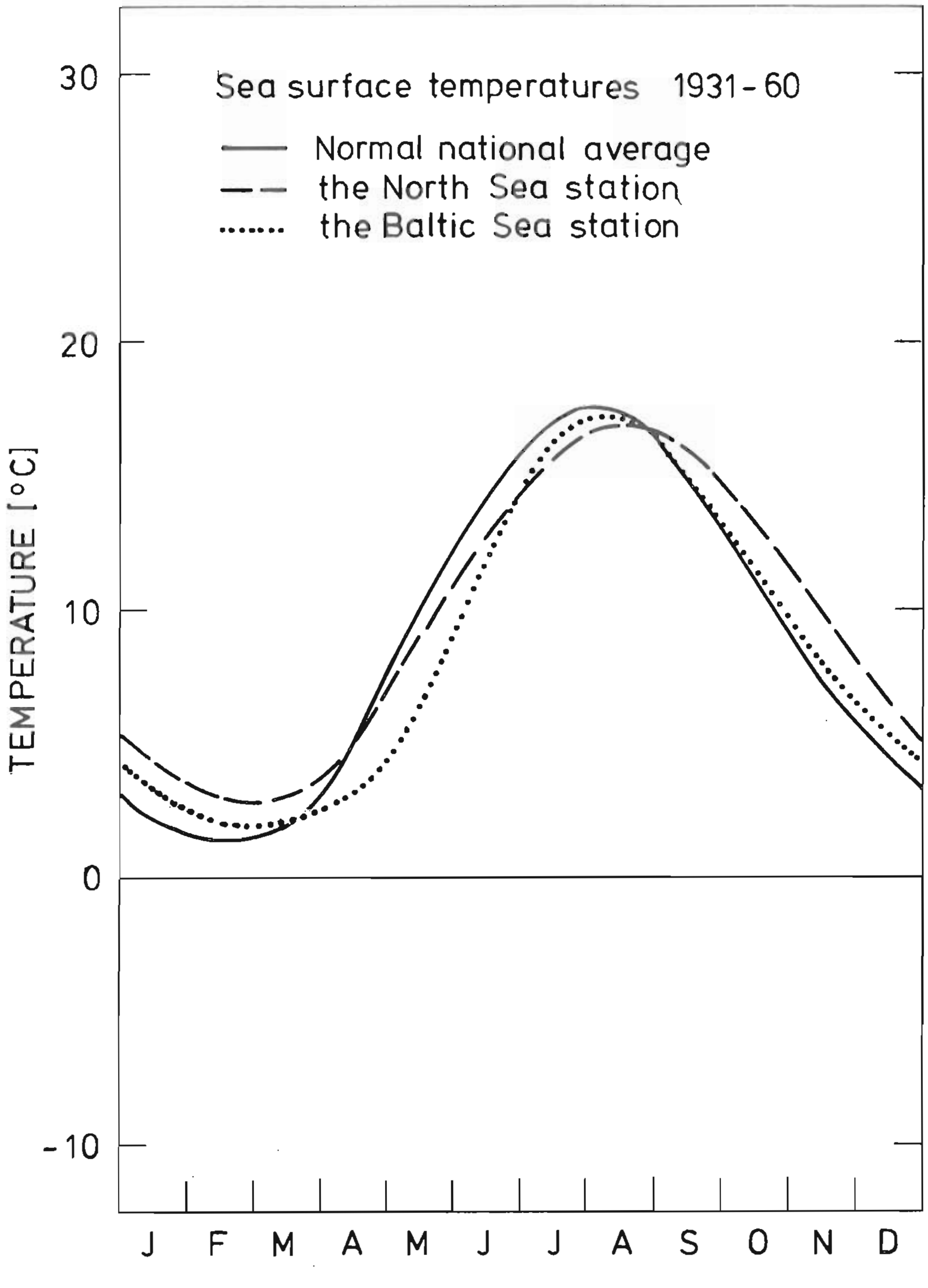

Fig. 4.8. Geographical differences in the yearly variation of sea-surface temperature in Denmark illustrated by comparing the normal from Fig. 4.6 with the temperatures measured at two stations (Simonsen, 1982) on the borderline between the Danish water and the two neighbouring larger water area: the North Sea and the Baltic Sea.

5. WINDS

The pressure field is the primary driving force behind the wind velocity and its variations. Above the atmospheric boundary layer (which is the lowest few kilometers of the atmosphere where conditions are directly influenced by the underlying surface) the wind velocity derives directly from a balance between two forces, the pressure gradient and the Coriolis force. The latter is an apparent force, which is active because the air moves in the rotating system of the Earth. Since the pressure gradient is directed out of areas with high pressure towards areas with low, and the Coriolis force is directed perpendicular to the wind velocity, it follows that the wind aloft will move along the pressure isobars as shown in Figure 5.1. This wind is called the geostrophic wind. As we descent through the atmospheric boundary layer a third force comes into play, namely the fric-

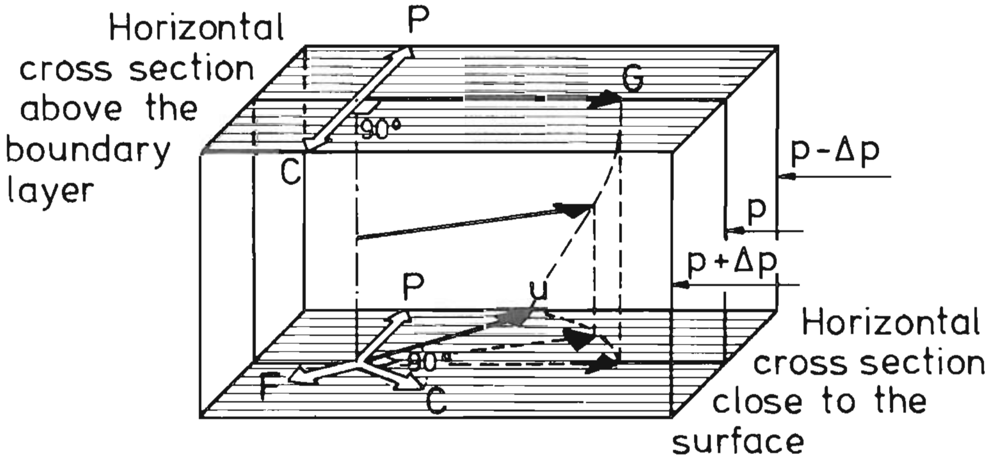

Figure 5.1. Schematic drawing showing how the wind velocity vector in the free atmosphere, called the geostrophic wind, is the result of a balance between two forces, the pressure gradient force, P and Coriolis force, C. In the boundary layer of the atmosphere a third force, the friction F, enters and modifies both the direction and speed of the air, u, relative to its velocity at the top of the boundary layer. The surfaces of constant pressure are indicated as well. The projection of the wind vectors onto a horizontal surface shows the socalled Ekman Spiral.

tion against the surface, which finally brings the air speed to zero at ground level. Since the friction as a force points opposite to the velocity direction, it follows that the wind velocity in the boundary layer is now determined by three forces: the pressure force, Coriolis force and frictional force. Consequently, the boundary layer velocity will have both another magnitude and direction than the velocity aloft. In Denmark it is typical for the wind aloft to point 20 degrees to the right of the wind at the surface, if one looks in the wind's direction. However, the angle may vary from about -10° to 50° depending on the horizontal and vertical temperature distribution within the boundary layer.

The friction between the air and the underlaying surface is communicated up through the boundary layer by turbulent mixing of the air parcels in this layer. This mixing process is partly mechanical, i.e. caused by the differing velocities present at various heights, but is also strongly influenced by the vertical temperature gradient in the boundary layer. It is enhanced if the boundary layer is warmest at the bottom and diminished if coldest there.

Since the wind velocity in climatology refers to the wind at 10 meters height, from the description above we can isolate three factors for the wind's diurnal -, annual-, and geographical variation:

a) Variations in the pressure field.
b) Variations in solar radiation and outgoing long-wave radiation yielding changes in the surface temperature and thereby in the boundary layer's vertical temperature gradient.
c) Variation in thermal properties and roughness of the surfaces. The degree of roughness of the surface influences the friction between air and surface, and the thermal properties influence the vertical mixing of the air in the boundary layer.

Below we consider these factors:

Pressure

Figure 5.2 shows the average surface isobaric lines for Denmark. It is seen that the pressure gradient across Denmark is small (1-2 mmHg) with high pressure towards the south. A comparison with Figure 5.1 shows that the average flow comes from the south-west, as has already been mentioned. The general pattern shown in Figure 5.2 does not change much during the year, although the isobars run slightly more west-east during the summer and slightly more south-north during winter.

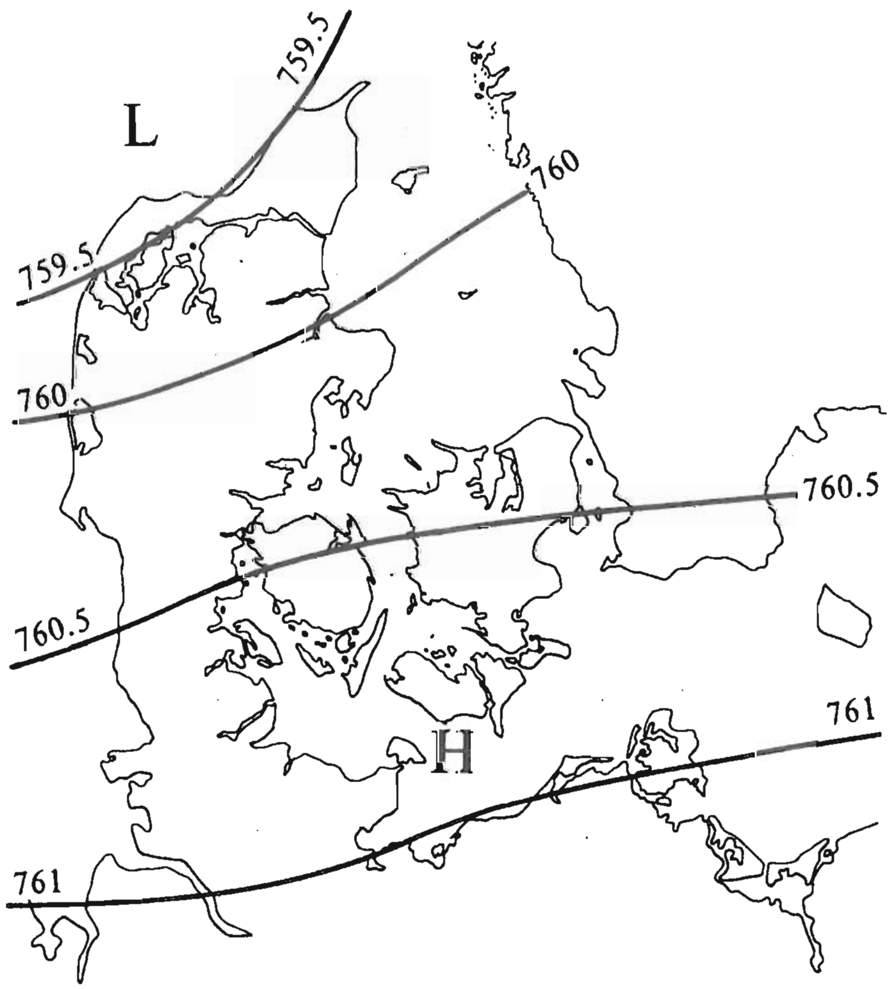

Figure 5.2. Normal isobar lines for Denmark [mm Hg] for the period 1931-60 (Lysgaard, 1968).

In Table B.2, rows 42 and 43,the yearly variation of the surface pressure is shown; it is seen to be of the same magnitude as the geographical variation across Denmark with 2-3 mmHg. The pressure is generally highest in the spring and lowest in July-August. Of greater interest is the short time variability of the pressure, since this reflects the coming and going of the frontal systems that incluences the Danish weather. Here the pressure is generally most variable during the winter with an average change of about 5-6 mmHg/day (Lysgaard, 1968), while it is more unvarying during the summer with an average change of about 2-3 mmHg/day. That this short-term pressure variability is associated with wind speed is clearly reflected in figure 5.5, where the wind speed aloft and at the coastal stations are especially seen to be higher during the winter than summer. Finally, it should be mentioned that the diurnal variation in the pressure due to solar heating is rather small, of the order of 0.5 mmHg.

Solar heating and radiation cooling

By definition the wind above the atmospheric boundary layer is not significantly influenced by the alternating heating and cooling of the surface in the diurnal cycle. However, as the ground heats up in the morning after a cool night, some of the heat is transferred to the air adjacent to it. This air, being warmer and therefore lighter than the cool air above, starts rising through the boundary layer. As a result, the vertical mixing of air in the boundary layer is intensified meaning that air parcels with the greater velocity aloft are mixed downwards towards the earth's surface. Therefore, the air velocity in most of the boundary layer will increase, while the difference in wind direction between two heights will decrease.

Conversely, after sunset the ground cools leading to diminished vertical mixing. As a result less air parcels from aloft are mixed down whereby velocity decreases in most of the boundary layer. Likewise, the wind direction's change across the boundary layer now increases.

We have already discussed the importance of these mixing phenomena in connection with Figure 4.3, where the heating and cooling of the boundary layer was shown for an average diurnal cycle in December, March, June, and September. The corresponding changes in speed and direction are shown in Figure 5.3a and b for the same four months. These figures show how the velocity in the lower layers increases, while the height variation of direction decreases, in responce to the daily heating. After sunset the processes reverse. The changes are seen to be most dramatic in summer with the larger amount of solar heating available, and

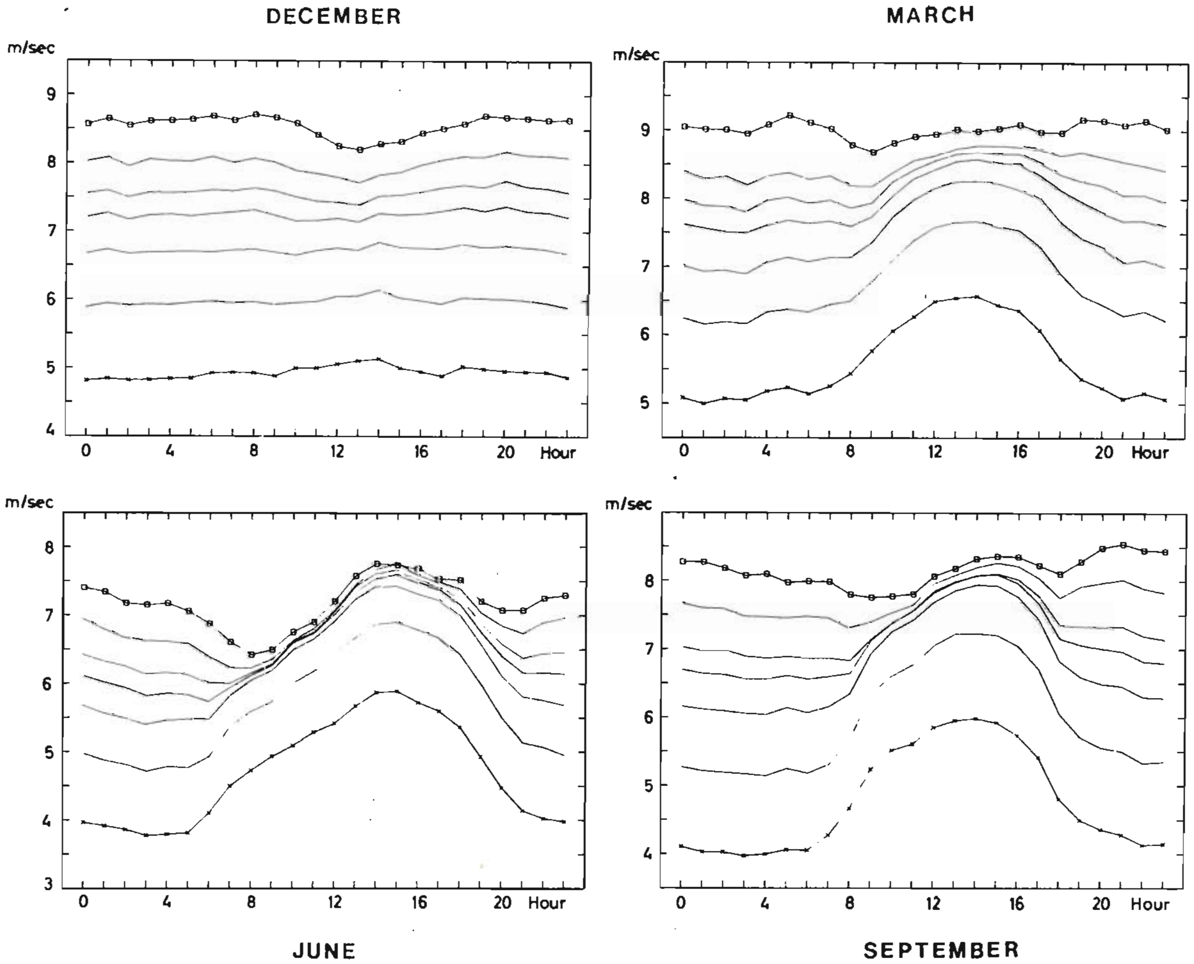

Figure 5.3a. The average variation through the day of wind speed with height, for the same four months for which the temperature variation is shown in Figure 4.3. The curves are taken from Petersen (1973) and describe average data from 1958-67 at Risø. The wind speed curves refer to 7, 23, 39, 56, 72, 96, and 123 m above terrain. 7 m is indicated by —x— and 123 m by —⊡— . The speed generally increases with height.

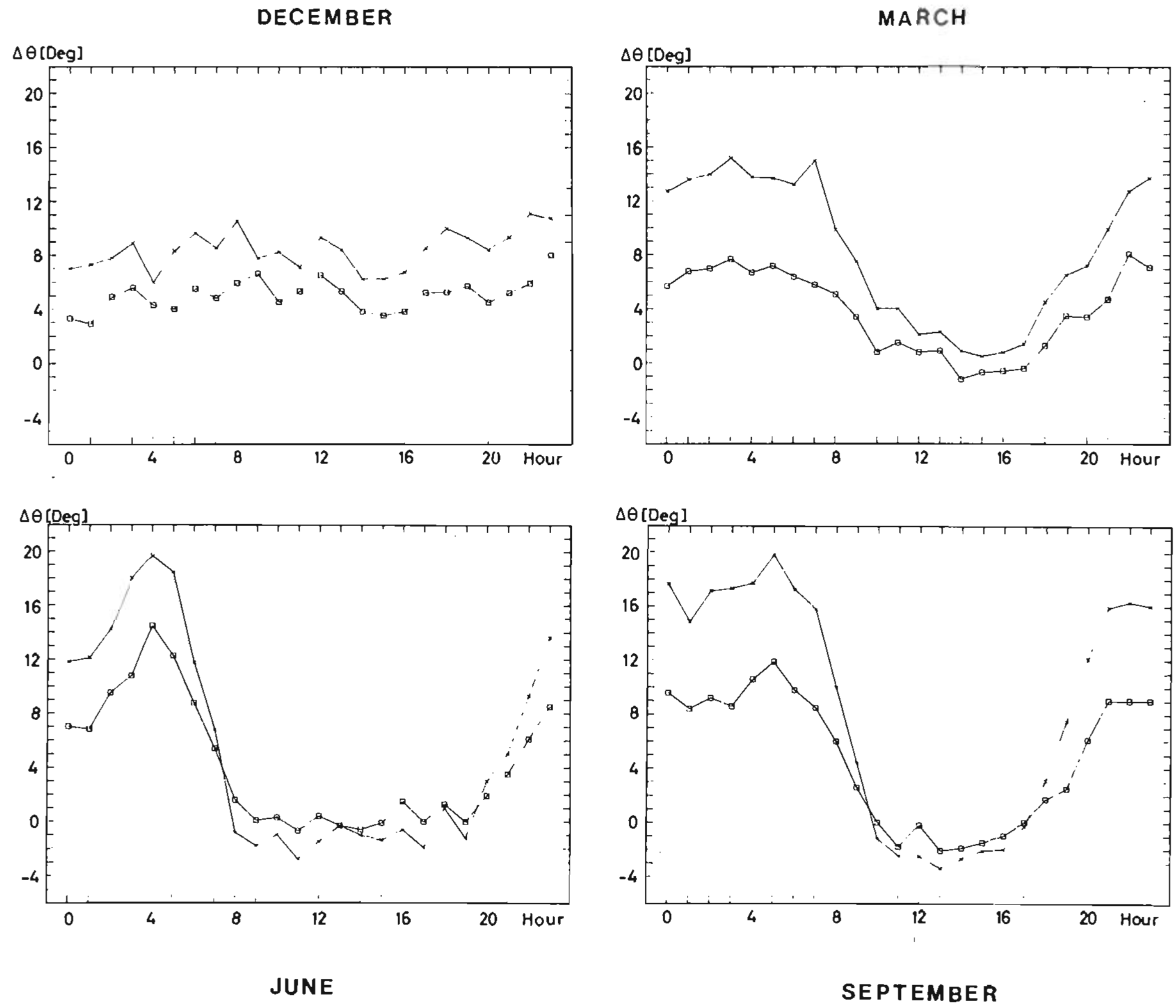

Figure 5.3b. The average variation through the day of the wind directional changes with height, for the same four months as Figures 5.3a and 4.3 (Petersen (1973)). -x-x- indicates directional difference between 123 m and 7 m and -□- between 56 m and 7 m. The angle is positive if the wind vector turns clockwise with height (see Fig. 5.1).

with lesser cloud cover to protect against surface radiational cooling during the night. In June the velocity at daytime at a 7-meter height is seen to have increased from about 4 m/s to 5.5 m/s; correspondingly, the wind direction's change over the lowest 100 m decreases from about 13^{o} to 0^{o}. In December, on the other hand, there are virtually no changes from night to day.

The diurnaly variations shown in Figures 4.3 and 5.3, measured at Risø, are averages over 10 years (Petersen, 1973). Individual days can, of course, show much deviation from the behaviour described here, due to the varying synoptic weather systems. Likewise geographical differences will be found owing to different surface characteristics. This leads us to our last reason for velocity variations, namely changes in surface characteristics.

Roughness and thermal characteristics of the surface

The roughness of the ground is responsible for its friction with the air. The rougher the ground the less is the wind velocity is in the lower part of the atmospheric boundary layer. The following terrain forms, all well known in Denmark are given in order of decreasing roughness: Cities, forests, fields, water, an unperturbed water surface being about the smoothest surface found in nature.

For the same geostrophic wind the velocity close to the ground will vary across Denmark in response to the terrain types found in different parts of the country. The influence of the surface roughness is largest in fairly large wind speed situations in which case the wind speed above the roughest kinds of terrain will be more than a factor of two less than that above the smoothest terrain form (which is water). Of course the effects will be largest if the terrain forms cover fairly extensive areas, since the frictional forces need to operate over a fairly long time and fairly large area to influence the wind speed fully.

Fig. 5.4 illustrates the differences between the average velocity inland and at the coast. The figure is based on data from 1931-60 (Frydendahl, 1971) and is constructed by Frydendahl (personal communication). The isolines shown should not be taken too quantatively due to the fairly low density of measuring stations. However, it clearly illustrates the influence of the roughness difference between land and water.

The thermal properties of the surface influence the vertical mixing of the air in the boundary layer. An interesting example can be found by comparing the wind outside and inside a larger metropolitan area. During the day and at high wind speeds the larger

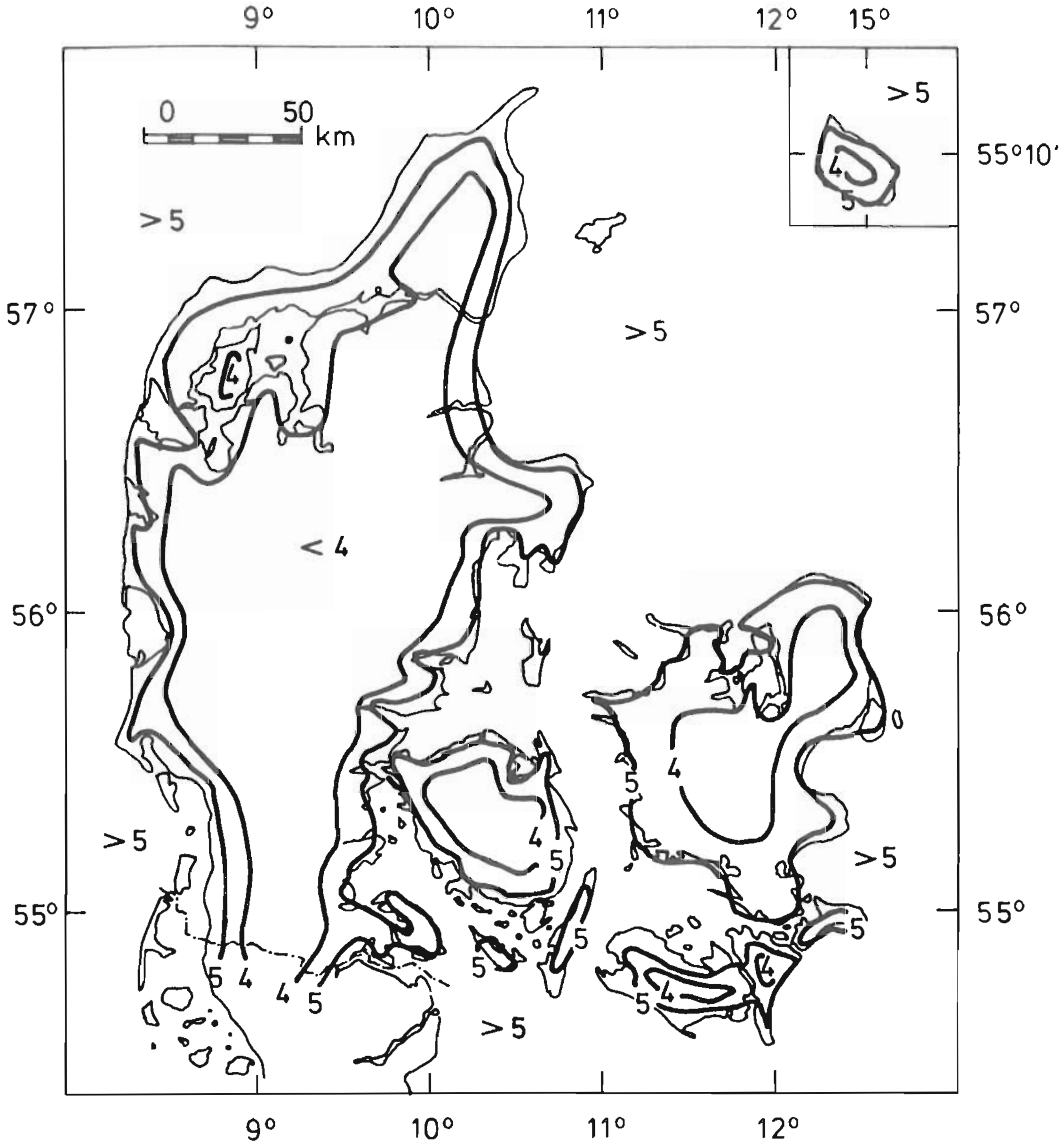

Figure 5.4. Isolines for wind speeds [m/s] in Denmark at 10 meter above the ground, based on data from 1931-60, compiled by Fryden-dahl (personal communication).

roughness of the city leads to a lower speed over the city than over the surroundings. However, at night at low wind speeds the larger temperature of the urban area (the so-called urban heat island) leads to increased vertical mixing and therefore a higher speed over the city than over the surroundings.

However, in Denmark the most important variation in surface thermal properties is that between land and water areas, as was discussed in Section 4. The resulting differences in seasonal and diurnal temperature variation will in turn result in different daily and seasonal variations of the wind speed over land compared with that over water. For example, it is likely that the differences in the yearly variation of wind speed at inland and coastal stations in Figure 5.5, is due at least partly to the differences in thermal properties between land and water. The higher geostrophic wind during the winter is associated with a

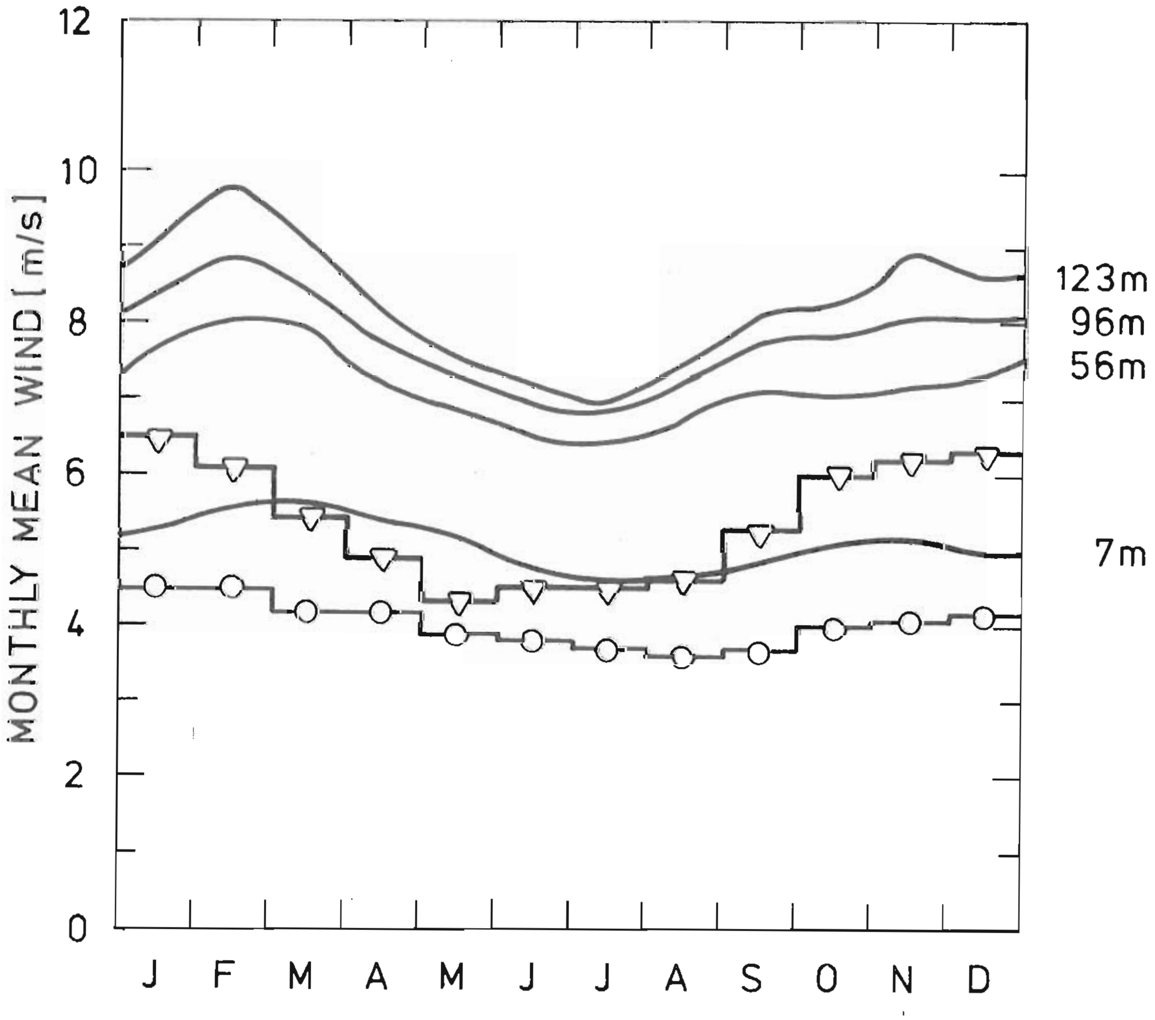

Figure 5.5. Monthly average wind speed obtained from 30 years of data from climatological measuring stations in Denmark (–▽–, -O-: coastal and inland stations, respectively) and from 10 years of data from Risø (Petersen, 1973). While the average difference in wind speed between coastal and inland stations are due to the roughness difference between water and land, the difference in the yearly variation of wind speed at the two types of stations is due to differences in thermal properties of land and water.

season where relatively little vertical mixing goes on over land, (compare the daily variation of wind speed in December, Figure 5.3a). In the winter and fall season, on the other hand, the water is warmer than the air (see Figure 4.6); for this reason winter and fall is associated with larger vertical mixing over the water than over the land.

Finally, we shall mention a few situations where thermal properties give rise to local circulation systems that influence wind statistics. In coastal regions the differential heating and cooling of land and water results in the so-called land-sea-breeze systems. When the warm air over land rises during the day it is replaced by cooler air from over the water. At night the process reverses.

These land-sea-breezes are fairly weak in Denmark, but they nevertheless will reduce the frequency of calm conditions at coastal stations relative to land stations (compare Table B2, rows 48, 49) and they have been detected in the climatological mean speed data as well (Frydendahl, personal communication). Under calm sunny conditions, the sea-breeze will typically reach its maximum in the early afternoon and can attain a velocity of about 2-3 m/s.

It could be mentioned that a parallel phenomenon is found around larger metropolitan areas, which are always warmer than the surroundings resulting in a weak windfield converging towards the city under calm conditions.

Finally, we shall mention the so-called orographic flows, which are associated with calm, clear nighttime conditions, where the vertical mixing is so small that the cool bottom air follows the topography seeking a downward direction. At inland positions these gravity flows will tend to accumulate cold air in valleys and other depressions in the landscape, where it will act as a kind of inert bubble of cold air giving low lying points an extraordinary low temperature and furthermore shielding them from what little wind velocity might still remain in the atmospheric boundary layer. For this reason low-lying inland positions have an especially high frequency of calm conditions.

In coastal regions these kinds of flow can obviously reinforce land-breeze systems, which under such conditions become particularly strong.

After this excursion into the mechanisms behind the variations of the wind field in time and space, we now turn to a more factual description of the wind climate in Denmark.

Wind statistics

Traditionally, wind statistics are often presented in terms of wind roses, which describe the joint frequency of both speed and direction in a single figure. An example of such a wind rose is given in Figure 5.6, based on 21 years of data at Risø.

This wind rose clearly shows the dominans of winds from between south and west. In summer they are more westerly than in winter, where the direction is more SW-S. (See Table B2, row 50, where the indicated mean directions have been found by averaging the wind vector over the periods indicated).

In spite of what has been said about the turning of the wind with height in individual cases, Table B9 shows that on the average there are insignificant differences of wind direction throughout the lowest 100 meters of the atmosphere.

From Figure 5.6 it can be deduced that only during 7% of the time is the wind speed less than 3 m/s 10 m above terrain. So, with a mean wind speed of about 5 m/s the Danish climate truly qualifies to be called windy. As discussed above, the wind speed exibits diurnal, seasonal, and geographical variation; it is generally lowest inland, 10-35% less than at the coasts; and it does show the least seasonal variation inland as well. The seasonal variation of the wind speed is shown in Figure 5.5, and is given in Table B2, rows 44, 45 and for the Risø data in Table B10. From Table B10 it is further seen that the wind speed at 7 and 56 meters height is roughly 40% and 15% lower respectively, than the speed at 123 m and that only small seasonal variations occur in these numbers,

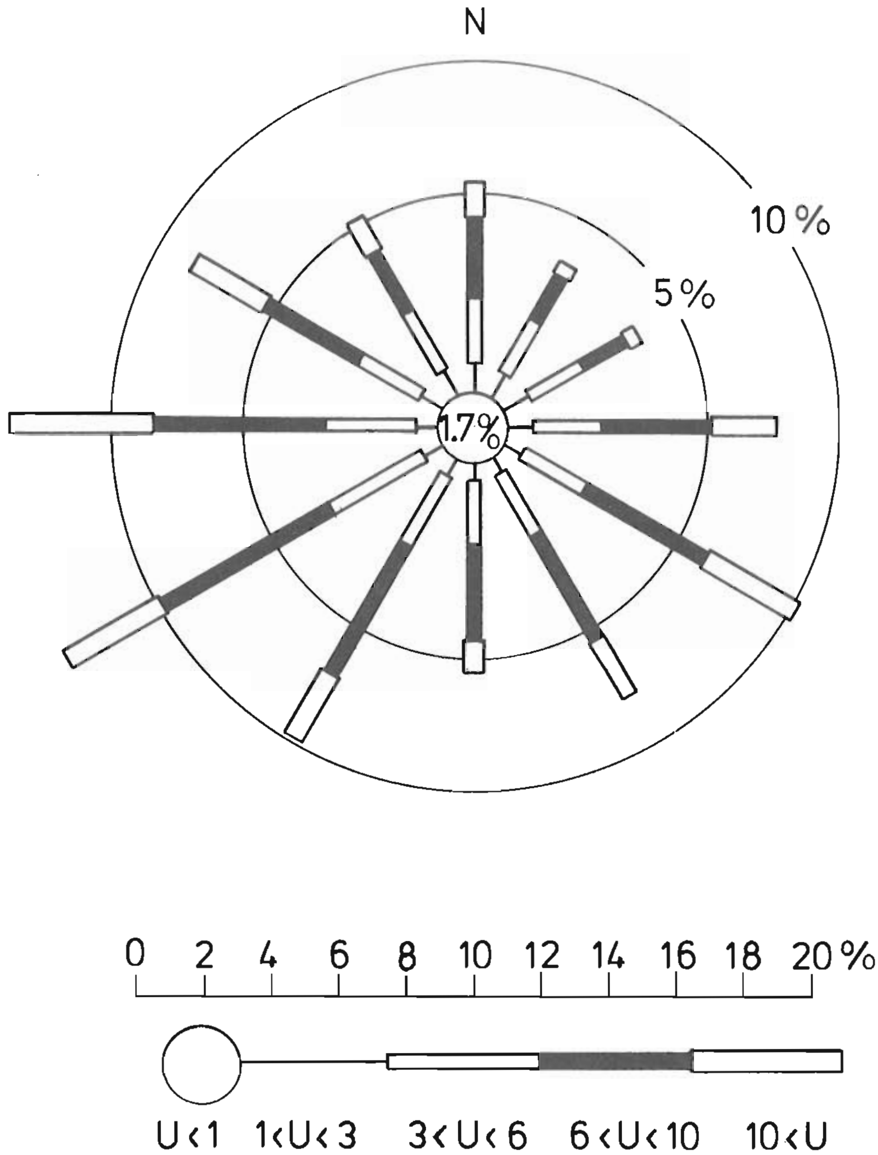

Figure 5.6. Joint distribution of wind speed and wind direction presented in the form of a wind rose based on data from Risø for the period 1958-1979. The wind speed is denoted U[m/s] .

although they are a bit smaller during the summer than winter, in keeping with the description given above. For a typical inland station, the seasonal variations must be expected to be larger however.

In Table B2, rows 46-49, the seasonal and geographical variations are shown for the frequencies of high wind speed (larger than 11 m/s) and calm situation; they are seen to follow the pattern already outlined with maximum frequency of high wind speed situations in winter and in coastal areas (17% of the time in January) and maximum frequency of calm condition at inland stations in summer (10% of the time in August). The country's yearly average frequency for high wind velocities is about 8% and for calm conditions about 5%.

The yearly averaged frequency distribution functions for wind speed for a number of heights are shown in Figure 5.7, where the distribution functions up to 123 m are based on 10 years of Risø data, while the function denoted G is the distribution function for the geostrophic wind above the atmospheric boundary layer,

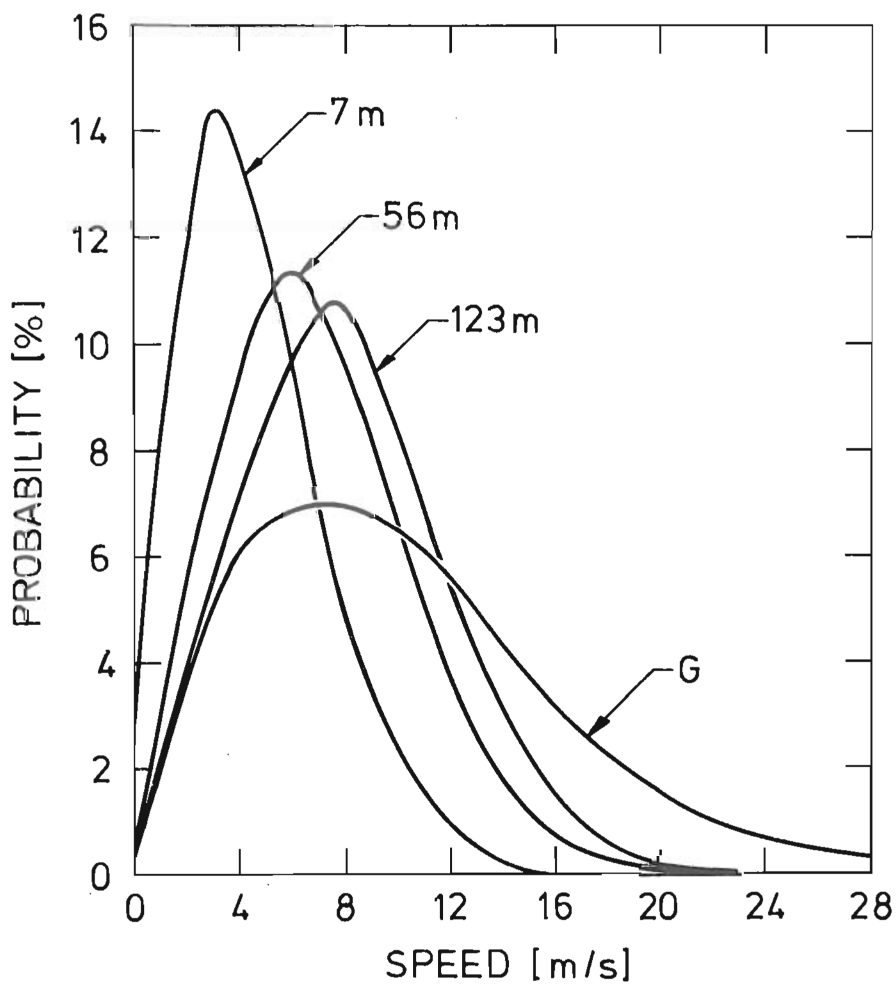

Figure 5.7. Average frequency of wind speed [% probability of any 1 m/s wind speed interval] at different heights at Risø, based on data from 1958-1967. The curve denoted G describes the distribution function for the geostrophic wind above the atmospheric boundary layer (Petersen et al., 1980).

taken from Petersen et al. (1980). It should be noted that the distributions, especially at lower altitudes must be expected to vary somewhat with location, in accordance with what has been said about the influence of roughness and thermal propererties of the surface (see also Petersen et al., 1980). Finally, a few words should be said about the steadiness of the wind direction. From Table B2, rows 51, 52 it is seen that the wind direction, in general, is steadier in summer than winter and early spring, while another study, table B11, shows that the wind vector on the average will vary within a 120° sector during one day, al-although it will stay within a 10° sector for a full day about once a year.

Over an arbitrary chosen 3-day period the wind vector will spend some time in all 30° sectors of the compass on the average, although it will spend most time close to its starting position (see Table B12). In an extreme case, it will actually stay within a 30° sector in 3 days about once a year (see Table B11).

The persistence of the wind direction has been extensively studied in Buch (1979) for a 10-year period at a number of measuring stations. It was found that about once a year the wind stays within 40° in 5 days, within 30° in 4 days, 20° in 2 days, and 10° in 1 day, roughly in accordance with the results shown in Table B11.

6. RECORDED CLIMATIC EXTREME VALUES IN DENMARK

To conclude this summary of Danish climate statistics and its interpretation we list below a number of extreme values that have been recorded over the last 100 years or so. When normal values are shown for comparison, the values given are national averages for the period 1931-60. It should be emphazised that the extreme values result from sampling networks with often very few stations, not because the parametres were not measured at more stations, but because the search for extreme values has been carried out only for a few of the data series.

SUNSHINE:

Largest number of sunshine hours per year: 2143 at Tylstrup, 1921. Normal value: 1729.
Largest number of sunshine hours per month: 381 at Lyngby, May 1947. Normal value for the month of June: 257.

PRECIPITATION:

Largest precipitation intensity: 70 mm during 15 min., Skive 1939.
Largest daily precipitation: 168.9 mm, Marstal 9.7.1931. Monthly normal value for August: 81 mm.
Largest monthly precipitation: 345 mm, Stordalshus, October, 1967.
Highest total annual precipitation: 1280 mmm, Brørup, 1980. Normal value 664 mm.
Lowest annual precipitation: 265 mm, Røsnæs, 1947.
Longest unbroken period with precipitation: 81 days, Norby, 6.11.1974 - 25.1.1975.
Longest unbroken period without precipitation: 49 days, Tylstrup, mainly during February, 1932.

TEMPERATURE:

Highest temperature: 36.4°C, Holstebro, 10.8.1975.
Lowest temperature: -31°C, Løndahl, 26.1.1942.
Highest 24-hour average: 27.3°C, Tarm, 11.7.1941.
Lowest 24-hour average: -21.6°C, Copenhagen 25.11.1942 and Tarm, 26.1.1942.
Largest number of summer days (max. temp. > 25°C) in a year: 50, Studsgaard 1947. Normal number 10.
Longest period of consecutive summer days: 16 days, Studsgaard, Aug. 1947.

Largest number of frost days (min. temp. $\leq 0^{\circ}C$) in a winter: 155, Tylstrup, 1940-41. Normal value: 88.
Longest period of ice days (max. temp. $\leq 0^{\circ}C$) 54 days, Lyngby, 1947. Normal value for a year: 23.

PRESSURE:

Highest measured surface pressure: 797 mm Hg, Skagen 23.1.1907.
Lowest measured surface pressure: 708 mm Hg, Skagen 20.2.1907.
Largest pressure increase in one hour: 5 mm Hg.
Largest increase in 24 hours: 40 mm Hg, Copenhagen, 1904.
Largest decrease in 24 hours: 36 mm Hg, Copenhagen, 1854.

WIND SPEED:

Largest mean velocity over one hour: 35 m/s, Hald, Christmas 1902.
Largest gust velocity: 43 m/s, Torsminde 16.2.1962 (the instrument had a time constant of about 4 sec.).

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APPENDIX A

DEFINITION OF METEOROLOGICAL CONCEPTS USED IN THE TEXT

Average max(min) temperature for a month:	Average of the daily maximum (minimum) temperature over a month for all stations.
Clear days:	Days with average cloud cover less than 20% of sky.
Cloud cover:	The cloud cover is indicated by the percentage of the sky, that is covered with clouds. The measure does not discriminate among clouds at different heights.
Cloudy days:	Days with average cloud cover larger than 80% of sky.
National average (NA):	The average value of all the data from the various measuring stations in Denmark.
Days with snow cover:	Part of the surface is observed to be covered by snow at 8 am.
Fog days:	Days where visibility at least once is reported to be less than 1 km.
Frost days:	Days with minimum temperature less than $0^{o}C$
Ice days:	Days with maximum temperature less than $0^{o}C$
Normal (N):	Means that the parameter values indicated refer to one of the main 30 year periods in climatology. (Mostly this report refers to 1931-60).
Precipitation days:	Days with precipitation measured as larger than 0.1 mm.

Pressure: Pressure is given either in mbar (millibar) or mm Hg (mercury). Standard atmospheric pressure is 1013.5 mbar or 760 mm Hg.

Relative humidity: The water vapour pressure in the air relative to the saturation water vapour pressure at the given temperature.

Snow days: Days where precipitation has been measured and snow has been observed.

Steadiness of wind direction: The steadiness of wind direction can either be given as the number of hours the wind vector may stay within a sector of a giving width. It can also be given as the ratio between the absolute value of the average velocity vector, and the wind speed averaged over the same period. If this measure is used stadiness is given in procent with 100% indicating constant wind direction.

Summer days: Days with maximum temperature larger than 25^{o}C.

Temperature: The air temperature is usually measured in degrees Celsius, and if nothing else is mentioned a temperature in climatology refers to the temperature 2 m above the terrain.

Turbidity: In meteorology, any condition of the atmosphere which reduces its transparency to radiation, especially to visible radiation.

Ordinarily, this is applied to a cloud-free portion of the atmosphere that owes its turbidity to air molecules and suspensoids such as smoke, dust, and haze, and to scintillation effects.

Wind direction: In meteorology the wind direction states which direction the wind comes from. When the direction is described in degrees, 0^{o} means north and the value increases clockwise around the circle.

Wind speed: Wind speed is usually measured in meter/sec., and refers in climatology to the speed at 10 meters height. The conversion between meters per sec. and a few other unit systems is:
1 m/s ≃ 0.3 km/hr ≃ 0.5 miles/hr ≃ 0.5 knot. Of special interest is the so-called Beaufort scale, where the wind speed (or rather the energy in the wind) is classified according to its influence on nature. Before meteorological instruments became easily available this scale was dominant, meaning that most older climatological records are compiled in Beaufort. The Beaufort scale is summarized in Table A1, which is taken from Frydendahl (1971).

Table A1. Beaufort's table for wind force and wind speed equivalence.

Beaufort number	Description	Velocity equivalent at a standard height of 10 metres above open flat ground			Specification for estimated speed over land	Specification for estimated speed over 'sea'
		Knots	Metres per second	Kilometres per hour		
0	Calm	<1	0-0.2	<1	Smoke rises Vertically	Sea like a mirror
1	Light air	1-3	0.3-1.5	1-5	Direction of wind shown by smoke-drift but not by wind vanes	Ripples with appearance of scales are formed, but without foam crests
2	Light breeze	4-6	1.6-3.3	6-11	Wind felt on face; leaves rustle; ordinary vanes moved by wind	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break
3	Gentle breeze	7-10	3.4-5.4	12-19	Leaves and small twigs in constant motion; wind extend light flag	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses
4	Moderate breeze	11-16	5.5-7.9	20-28	Raises dust and loose paper; small branches are moved	Small waves, becomming longer; fairly frequent white horses
5	Fresh breeze	17-21	8.0-10.7	29-38	Small trees in leaf begin to sway, crested wavelets form on inland water	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray)
6	Strong breeze	22-27	10.8-13.8	39-49	Large braches in motion; inconvenience felt when walking against the wind	Large waves begin to form; the white foam crests are more extensive everywhere (probably some spray)
7	Near gale	28-33	13.9-17.1	50-61	Whole trees in motion; inconvenience felt when walking against the wind	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind
8	Gale	34-40	17.2-20.7	62-74	Breaks twigs off trees; generally impedes progress	Moderately high waves of greater length; cages of crests begin to break into the spindrift. The foam is blown in well marked streaks along the direction of the wind
9	Strong gale	41-47	20.8-24.4	75-88	Slight structural damage occurs (chimney-pots and slates removed)	High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple, tumble and roll over; spray may affect visibility
10	Storm	48-55	24.5-28.4	89-102	Seldom experienced inland; trees uprooted; considerable structural damage occurs	Very high waves with long overhanging crests; foam, in great patches, is blown in dense white streaks along the wind. On the whole the surface of the sea takes a white appearance; the tumbling of the sea becomes heavy and shocklike; visibility affected
11	Violent storm	56-63	28.5-32.6	103-117	Very rarely experienced; widespread damage	Exeptionally high waves; the sea is completely covered with long white by patches of foam lying in the direction of the wind; the edges of the waves are blown into froth; visibility affected
12	Hurricane	64 and over	32.7 and over	118 and over		The air is filled with foam and spray; sea completely white with driving spray; visibility very sereously affected.

APPENDIX B

Table B1. The variation through the year in Denmark of sunrise and sunset [Danish Normal Time]. Also shown is the time of and declination [degrees] of culmination (Petersen, 1973). The declination is the angular distance of the sun north of Equator. At the time of culmination the Zenith angle equals the lattitude (in Denmark ~ 56° N minus the declination.

The first day in the month of	Sunrise	Culmination	Declination at culmination	Sunset
January	8.42	12.13	-23.03	15.45
February	8.07	12.23	-17.17	16.40
March	7.03	12.22	-7.27	17.43
April	5.43	12.14	4.41	18.46
May	4.29	12.07	15.11	19.46
June	3.36	12.07	22.06	20.40
July	3.33	12.13	23.06	20.54
August	4.17	12.16	17.56	20.13
September	5.16	12.10	8.10	19.02
October	6.14	11.59	-3.19	17.43
November	7.18	11.53	-14.32	16.28
December	8.17	11.59	-21.51	15.40

Table B2. Variation with the months of the year of a number of Danish meteorological parametres (monthly average). The material is compiled primarily from Meteorologisk Institut (1970), Frydendahl (1971), Lysgaard (1968) Teknologisk Institut (1978), and Stampe (1977).

Parameter NA = National Average N = Normal (1931-60)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Row No
Abs. max. temp. 1874-1980 [°C]	11.8	15.5	21.2	28.2	32.8	35.5	35.3	36.4	32.3	24.1	18.5	14.5	36.4	1
Abs. max. temp. at any station [°C], N	9.2	9.8	15.0	21.1	27.4	29.7	31.2	29.7	25.3	19.4	13.6	10.6	31.2	2
Abs. max. temp. [°C] NA, N	6.8	6.7	10.7	16.5	23.6	26.0	26.9	24.8	21.5	16.4	10.9	8.2	16.8	3
Average max. temp. NA, N [°C]	2.0	2.2	5.0	10.2	15.7	19.0	21.1	20.6	17.2	12.0	7.2	4.1	11.3	4
Average temp. NA, N [°C]	-0.1	-0.4	1.7	6.2	11.1	14.5	16.6	16.3	13.1	8.7	4.9	2.2	7.9	5
Average min. temp. NA, N [°C]	-2.4	-3.0	-1.3	2.4	6.3	9.7	12.2	12.2	9.7	5.9	2.6	0.1	4.5	6
Abs. min. temp. NA, N [°C]	-9.9	-10.0	-7.2	-3.0	0.5	4.5	7.3	7.0	2.9	-1.4	-5.2	-8.3	-1.9	7
Abs. min. temp. at any station [°C], N	-17.6	-17.2	-14.2	-8.1	-4.2	-0.5	2.7	2.2	-0.9	-4.5	-7.2	-14.0	-20.5	8
Abs. min. temp. 1874-1980 [°]	-31.0	-29.0	-27.0	-19.0	-8.0	-3.5	-0.9	-2.0	-5.6	-11.9	-21.3	-24.4	-31.0	9
Summerdays (max temp. greater than 25°C) NA, 1938-60	0.0	0.0	0.0	0.0	0.6	2.1	3.8	3.4	0.3	0.0	0.0	0.0	10.2	10
Frost days (min. temp.) less than 0°C) NA, N	21.0	19.0	19.0	6.0	1.0	0.0	0.0	0.0	0.1	2.0	6.1	14.0	88.2	11
Ice days (max. temp. less than 0°C) NA, 1938-60	8.9	8.5	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.8	23.1	12
Max. sunshine hours NA, 1874-1978	82	127	200	275	381	340	334	338	224	162	70	58		13
Sunshine hours Jutland and the Isles, N	41	65	127	181	256	257	247	221	166	98	42	28	1729	14
Sunshine hours Bornholm	38	56	121	189	271	284	257	220	184	98	36	27	1783	15

Min. sunshine hours, NA, 1874-78,	12	11	50	87	145	181	158	151	109	35	22	6	-	16
Total solar radiation on a horizontal plane [kWh/m²] 1966-76 Højbakkegaard														
Maximum	17.1	35.0	82.1	132.4	168.7	195.0	175.8	155.9	90.3	51.1	22.2	12.8	1072.2	17
Average	13.2	29.2	72.0	115.9	153.3	179.0	162.5	138.5	82.9	42.3	18.5	11.1	1018.5	18
Minimum	9.2	23.4	61.9	99.3	138.0	163.1	149.2	121.2	75.6	33.6	14.8	9.3	964.7	19
Diffuse solar radiation on horizontal plane [kWh/m²] 1966-76 Højbakkegaard														
Maximum	9.8	19.2	39.4	57.2	75.1	84.1	81.0	60.5	40.7	25.1	11.9	7.6	489.9	20
Average	8.5	16.8	35.6	51.6	70.3	76.1	76.4	57.0	39.5	22.2	10.6	6.6	472.8	21
Minimum	7.1	14.3	31.9	46.6	65.5	68.2	71.8	53.5	38.3	19.2	9.3	5.6	455.8	22
Cloud cover [% of sky] NA, N	74	72	62	58	53	55	58	57	56	67	77	78	64	23
Clear days [cloud cover less than 20% of sky] NA, N	1.9	2.0	4.3	3.9	5.0	3.9	3.2	3.0	3.5	2.1	1.2	1.3	35	24
Cloudy days [cloud cover greater than 80% of sky] NA, N	16.1	14.0	11.5	8.6	6.8	6.5	7.3	7.1	6.8	11.7	16.0	17.3	130	2
Relative humidity [%] NA, N	89	87	85	78	72	73	76	79	83	86	89	91	82	26
Relative humidity [%], Odense														
8.00 am	91	90	89	84	77	77	81	85	89	91	92	91	-	27
12.00 pm	88	83	77	69	62	64	66	68	72	77	86	89	-	28
9.00 pm	91	90	89	86	81	83	85	89	90	91	91	92	-	29
Water vapour pressure [mbar] NA, N	5.3	5.2	5.9	7.3	9.5	12.0	14.4	14.7	12.5	9.7	7.7	6.5	8.8	30
Days with fog NA, N	10	9	10	6	4	2	2	2	3	4	6	9	67	31
Days with thunder NA, N	0.09	0.03	0.06	0.43	1.3	1.6	2.8	2.8	1.4	0.48	0.17	0.13	11.3	32
Days with snow NA, N	7.1	6.3	4.7	1.3	0.2	0.0	0.0	0.0	0.0	0.2	1.0	4.2	25	33
Days with snowcover NA, 1951-71	12	12	7	2	0	0	0	0	0	0	1	8	42	34
Max. precipitation [mm], NA, 1874-78	98	91	100	98	86	124	140	167	148	169	153	113	-	35
Average precipitation [mm], Jutland and the Isles, N	55	39	34	39	38	48	74	81	72	70	60	55	664	36
Average precipitation [mm], Bornholm, N	54	39	31	33	34	43	60	61	63	63	58	54	594	37

Min. precipitation [mm], NA, 1874-1978	8	2	7	3	9	10	15	10	18	12	13	7	-	38
Days with precipitation (precipitation larger than 0.1 mm) NA, N	15	13	10	12	10	11	13	14	14	15	16	16	159	39
Days with large precipitation (precipitation larger than 10 mm) NA, 1938-60	1.1	0.56	0.76	0.61	0.89	1.1	2.1	2.6	1.9	1.6	1.6	1.1	16	40
Max. precipitation in 24 hours 1874-1978	50.0	61.8	54.8	66.5	77.3	153.1	168.9	151.2	132.7	83.1	59.9	46.4	168.9	41
Average pressure (1000 mbar+) Ålborg, N	12.8	12.4	14.9	17.4	15.3	13.0	11.7	11.8	12.0	12.8	12.4	11.0	12.7	42
Average pressure (1000 mbar+) Kastrup, N	13.2	13.5	15.7	13.6	16.0	14.3	12.5	12.9	14.5	14.4	13.6	12.9	13.5	43
Mean wind speed [m/s] NA, N														
Coast stations	6.5	6.1	5.4	4.9	4.3	4.5	4.5	4.6	5.3	6.0	6.2	6.3	5.4	44
Inland stations	4.5	4.5	4.2	4.2	3.9	3.8	3.7	3.6	3.7	4.0	4.1	4.2	4.0	45
Occurrence of wind speed larger than 11 m/s [% of time] NA, N														
Coast stations	17	14	10	8	6	6	6	6	10	13	15	15	10	46
Inland stations	8	8	7	6	4	4	3	4	5	6	6	6	6	47
Occurrence of calm conditions [% of time] NA, N														
Coast stations	2.0	2.5	3.8	4.1	5.2	4.8	4.6	4.4	3.2	2.5	2.4	2.0	3.5	48
Inland stations	6.1	5.5	6.1	5.3	6.4	6.4	7.4	9.4	9.2	7.6	7.1	6.5	6.9	49
Mean wind direction [sector] NA, N	SSW	SW	ESE	W	NW	W	W	W	W	SW	SSW	SSW	SW	50
Steadiness for direction [%] NA, N														
Coast stations	19	10	7	18	12	41	46	36	35	24	24	26	21	51
Inland stations	21	14	7	22	10	42	46	37	38	26	24	28	23	52

Table B3. (1): Frequency [percentage of days in a year] of daily precipitation, measured at the Veterinarian University in Copenhagen in the period 1861-1960 (Lysgaard, 1969). (2): Frequency of hourly precipitation [percentage of hours in a year], measured at Risø in 1970-75, 1978 (Gyllander and Widemo, 1980). Precipitation less than 0.1 mm/day or 0.1 mm/hr is formally classified as dry weather in the period considered (0.1 mm is considered the lowest measurable amount of precipitation).

mm precipitation per (1)day, (2)hour	0-0.1	0.1-1	1.1-5	5.1-10	10.1-15	15.1-20	>20
(1) Frequency %	53	18	18.5	7	2	0.7	0.6
(2) Frequency %	92.80	5.87	1.26	0.05	0.01	0.008	0.002

Table B4. Frequency [percentage % of time] of weather phenomena related to precipitation, during the months of the year. The table is based on data taken at Copenhagen Airport in Kastrup in the period 1949-58, as given by Statens Luftfartsvæsens Flyvevejrtjeneste (1961) and corresponding unpublished material for the years 1959-68 from the same institution. The symbol indicates that although the weather phenomena have been observed in the particular months, the average frequency has been less than 0.05%. The data are based on observations every half hour.

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Fog	5.1	6.2	5.0	2.4	0.8	0.4	0.3	0.7	1.2	2.8	2.1	3.9
Rain	8.0	6.5	6.0	11.6	10.2	9.2	12.0	11.4	9.9	13.1	16.0	12.0
Drizzle	4.3	3.0	2.1	1.5	1.1	0.8	1.3	1.0	1.4	3.2	5.8	4.9
Freezing rain	0.8	0.8	0.3	-	-	-	-	-	-	-	-	0.2
Sleet	2.0	1.3	1.1	0.7	-	-	-	-	-	-	1.2	2.6
Snow	9.1	10.3	5.8	1.4	-	-	-	-	-	-	0.7	4.8
Hail	-	-	0.1	-	-	-	-	-	-	-	-	-
Thunder	-	-	-	-	0.1	0.4	0.4	0.4	0.3	0.1	-	-

Table B5. Corrected and uncorrected standard normals for precipitation [mm] for 1931-60, National average (Allerup and Madsen, 1981). The uncorrected values corresponds values corresponds roughly to Table B2 row 36, the corrected values are obtained through a study of the different error sources associated with standard rain gauges, mainly flow distortion around the gauges.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Corrected [mm]	67	48	40	46	44	55	83	89	81	80	70	64	767
Uncorrected [mm]	55	39	33	39	38	48	74	80	72	70	60	54	662

Table B6 The relative mass distribution [%] of liquid and solid precipitation, consisting mainly of snow but also hail and partly sleet (Allerup and Madsen, 1981).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Rain [%]	59	56	57	93	100	100	100	100	100	100	97	76	88.7
Snow [%]	41	44	43	7	0	0	0	0	0	0	3	24	11.3

Table B7. Summary of statistics concerning the yearly variation of thunder and lightning. The frequency of thunder in percentage of time is taken from Table B4, while the number of days with thunder is taken taken from Table B2. The lower rows are calculated from lightning flash counts at 22 stations across the country, as shown in Figure 3.7, in the period 1965-77. The symbol indicates that no measurements have been carried out in these months. It should be noted that the numbers of the different months cannot be considered of equal statistical significance, since both the measuring period and the number of stations have varied from year to year. The number of counts corresponds to lightnings per 100 km^2, and it is worth noticing that the average number of days with more than 5 counts roughly corresponds to twice the number of days with thunder as given by row 2.

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Frequency of thunder from Table B4 [%]	-	-	-	-	0.1	0.4	0.4	0.4	0.3	0.1	-	-
Days with thunder from Table B2.	0.09	0.03	0.06	0.43	1.3	1.6	2.8	2.8	1.4	0.48	0.17	0.13
Average number of lightning flash counts, n	0	-	-	29.5	115	278	321	232	118	25.9	11.4	2.4
Standard deviation on n, σ	0	-	-	20.9	75.2	210	190	135	105	25.0	15.2	2.3
Maximum number of counts af any stations	0	-	-	419	807	1949	1899	1373	1088	259	245	10
Average number of days with number of counts larger than 5	0	-	-	0.6	2.1	3.2	4.1	3.5	2.3	1.0	0.5	0.2
Maximum number of days with number of counts larger than 5	0	-	-	4	8	10	10	13	11	7	4	1

Table B8. Number of days with ice in the Danish waterways in the categories: 5(heavy ice), 6(severe drift ice) and 7(pack ice). Years without ice in these categories are not included in the table. The table is based on the yearly reports from Statens Istjeneste (1908-09,....., 1971-72).

Place	Øresund The Sound			Storebælt Great Belt			Lillebælt Little Belt		
Category	5	6	7	5	6	7	5	6	7
1908 - 09	-	6	6	-	11	11	-	1	-
1911 - 12	-	2	1	-	9	3	-	3	3
1916 - 17	0	19	11	6	1	3	3	6	1
1921 - 22	16	7	1	9	19	8	12	3	3
1923 - 24	8	28	23	-	4	6	-	16	-
1928 - 29	8	24	33	23	12	29	32	11	20
1939 - 40	28	35	22	31	34	14	41	8	35
1940 - 41	40	36	36	18	25	3	46	2	-
1941 - 42	67	45	23	43	54	37	67	11	-
1946 - 47	49	29	42	50	22	58	66	13	-
1953 - 54	6	5	17	-	5	-	-	13	6
1954 - 55	6	11	17	-	3	-	5	-	-
1955 - 56	22	16	16	-	6	13	15	6	11
1962 - 63	14	35	54	1	37	24	38	14	12
1965 - 66	3	12	2	-	4	1	4	8	5
1969 - 70	17	18	10	-	17	1	-	11	39
1971 - 72	-	-	-	-	9	-	-	-	-

Table B9. Frequency of wind direction [percentage of time] at different heights at Risø. The width of each sector is 30°, sector 0 is north ± 15°, sector 3 is east ± 15°. Based on data from 1958-67.

Wind sector	N 0	1	2	E 3	4	5	S 6	7	8	W 9	10	11
Height												
7 meter	6.3	4.8	5.0	7.8	9.2	10.0	8.7	11.0	13.0	10.6	8.5	5.1
56 -	5.5	4.3	5.0	6.5	9.8	9.8	7.8	10.3	12.3	12.7	10.3	6.0
123 -	6.1	4.9	3.9	6.9	9.3	89.0	7.6	11.3	14.4	12.0	7.6	6.0

Table B10. Mean wind speed at Risø [m/s] as a function of the season and height [m] above terrain. Based on data from 1958-67.

Height	Jan.	Feb.	March	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
7 meter	5.25	5.54	5.60	5.32	5.20	4.70	4.59	4.59	4.78	5.00	5.12	4.93	5.05
56 -	7.66	8.04	7.93	7.13	6.89	6.50	6.45	6.72	7.12	6.95	7.15	7.25	7.15
96 -	8.34	8.84	8.49	7.69	7.38	6.90	6.81	7.26	7.76	7.78	8.03	8.00	7.77
123 -	9.03	9.74	9.00	8.05	7.48	7.17	6.87	7.41	8.16	8.20	8.92	8.55	8.22

Table B11. Steadiness of wind directions as a function of sector width (all directions) from Thykier-Nielsen (1968). Risø data from 1965.

Sector width [degrees]	10	20	30	40	50	60	90	120	170
Average steadiness [hours]	1.3	3.0	4.8	6.8	9.0	11.3	17.6	26.6	40.5
Maximum steadiness [hours]	26	42	72	74	109	150	194	249	341

Table B12. Frequency [percentage of time] of wind direction around the start direction in 72 hours. The width of each direction sector is 30°. The table is an average for all start directions, but changes only insignificantly for different start sectors.

Sectors counterclockwise from start sector						Start sector	Sectors clockwise from start sector				
- 6	- 5	- 4	- 3	- 2	- 1	0	+ 1	+ 2	+ 3	+ 4	+ 5
3.5	3.9	4.4	5.8	8.0	14.0	23.0	14.3	8.9	6.1	4.5	3.7

Table B13. Variation with month of the surface water temperature in Denmark for the period 1931-60. Compiled from data in Simonsen (1982) (C. Simonsen, personal communication).

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Abs. max. temp. 1931-60 [°C]	7.3	6.1	7.9	13.2	20.2	23.2	24.8	23.9	22.0	16.4	13.3	10.8	24.8
Average max. temp. [°C] NA, N	3.9	2.7	3.4	7.4	13.1	16.8	19.2	18.9	17.0	13.4	9.4	6.4	
Average temp. [°C], NA, N	2.2	1.5	2.0	5.0	9.8	14.2	17.0	17.2	15.0	11.2	7.4	4.4	
Average min. temp. [°C], NA, N	0.6	0.2	0.7	2.8	6.8	11.6	14.7	15.4	12.9	8.8	5.3	2.4	
Abs. min. temp. 1931-60 [°C]	-1.8	-1.9	-1.8	-1.1	0.3	5.5	9.3	8.3	8.2	3.3	-0.4	-1.5	-1.9

APPENDIX C

Fig. C1. Map of Denmark (Gyldendals store Opslagsbog Bind 1, Gyldendal, København, 1967).